Combining eco-social and environmental indicators to assess the sustainability performance of a food value chain: A case study

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ABSTRACT

Stakeholders are increasingly demanding transparency on food value chain sustainability performance. Today there is no standard framework to meet this demand and support defining indicators to be used to conduct an overall sustainable performance assessment. This paper mobilizes existing frameworks and indicators to build new sustainable performance metrics for actors willing to work together for their value chain sustainability. Popular methods or tools for assessing dimensions of agrifood products or activities are selected and analyzed to determine how they could contribute to this metric. The analysis aims to distinguish the sustainable development pillars addressed (economic, environmental and/or social), the frames concerned (life cycle thinking or not; multi actor or not), and the focus of performance measured (drivers, pressures, states, impacts, responses). This categorization is then used to develop a proposal for specifications adapted to food value chain sustainability performance assessment. The applicability of the framework is demonstrated through a case study in a pork agrifood value chain.

1. Introduction

According to Rastoin and Ghersi (2010), there are two models of agribusiness that coexist on a global scale: a very innovative mass market on one side, and traditional markets based on family and peasant agriculture on the other. On the mass market side, practices and economic activities have undergone profound changes over the last twenty years. Agribusiness has increasingly organized its mass goods and services trade into networks of actors linking upstream agricultural activities to downstream distribution (Ercsey Ravasz et al., 2012; Taylor, 2005; Temple et al., 2011). A consequence of this strategy has been widespread loss of consumer confidence in food brands—a perception crystallized by health scandals related to food traceability (Schwagele, 2005). This shift has taken place in a context of tertiarization of industrial and agricultural activities (Lorino and Nefussi, 2007), and has gradually increased the importance of service as part of food product value for the end user. Information and communication on food products are therefore important reassuring and differentiating factors for food brands, which makes it vital for actors in a food value chain to efficiently and effectively communicate on the sustainable performance of their products and activities in order to differentiate in an ultra competitive marketplace.

2. Background

More and more agribusiness literature is highlighting the growing importance of assessing the sustainable performance of food products or processes (European Food SCP Round Table, 2012; Raymond, 2012), in response to pressure from several fronts: so cietal demand translated by the political authorities through eco nomic incentives, taxes or regulations (Burlingame and Demini, 2012; European Commission Parliament and Council, 2006; Gadema and Oglethorpe, 2011; Tukker, 2006), the willingness of end product producers to meet consumer expectations (European Commission Parliament and Council, 2007; Hoolohan et al., 2013; McWatters et al., 2006; Wiedmann et al., 2014) and a desire of many producers and processors to make sense of their activities (Lémery, 2003).

The Triple Bottom Line (Elkington, 1994) lends the same importance to social, economic and environmental aspects of sus tainability. Much of the scholarship has shown that the environ mental dimension is much more represented in ecodesign research

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than the others (Beske et al., 2014; Bocken et al., 2013; Gold et al., 2013; Lozano, 2008; Seuring, 2013). However, in the past decade, there has been upswell in effort to integrate the social dimension into sustainability assessment. Agrifood firms today are considered (by public authorities, NGOs and consumers) co responsible for addressing social issues, alongside public authorities and civil society (Deverre and Lamine, 2010; Gendron et al., 2004). The scholarship has proposed social metric frameworks in agricultural production (Falque et al., 2014; Macombe et al., 2011), but LCA experts continue to report persistent difficulties (wide range of stakeholders and impact scales, data collection) in accounting for the social dimension, whether for assessing the sustainability performance of a product's lifecycle (Jørgensen et al., 2008) or whole value chains (Sarkis et al., 2011; Seuring, 2004; Seuring et al., 2008; Seuring and Müller, 2008; Srivastava, 2007; Zhu et al., 2008). Moreover, many recent publications have advocated accounting for the impacts of processed food products throughout the whole lifecycle rather than splitting agricultural production and processing/distribution of the end product, as commonly done (De Camillis et al., 2012; Ercsey Ravasz et al., 2012; Grimm et al., 2014; Payen et al., 2015). Sustainable performance assessment of food value chains thus needs to be conducted throughout the whole product lifecycle and for both social, economic and environmental aspects. However, there is still no consensus framework for a value chain assessment (Jørgensen et al., 2008).

In the agrifood sector, more than any other industrial sector, globalization has resulted in a downstream concentration of power, held by the processing and distribution companies that thus have a major impact on chain wide governance (Allaire, 2010; Bonanno, 1991; Friedland, 1991). In this context, product or process specifications are vertically driven in a downstream–upstream direction and transferred step by step up to the farmer from his customer (Meynard et al., 2017). This coordination of operations runs counter to the sustainable value chain governance proposed by Porter and Kramer (2011). In the latest model of sustainable value chain, the actors may conjointly define their sustainable strategy for three reasons: (1) to better integrate the impacts of their interacting activities; (2) as the will to monitor sustainability is new, it is difficult to obtain data, so collaboration between value chain actors can facilitate the process; and (3) to co decide the appropriate indicators for monitoring the sustainability performances of the value chain in line with their strategy. In this perspective, setting up indicators for a common strategy is considered the first step towards a common and shared definition of sustainability, and any effort to offer all value chain actors a vision of the consequences of their decisions on their value chain sustainability (VCS) needs to juxtapose a wide variety of indicators.

This paper mobilizes existing frameworks and indicators to build new sustainable performance metrics for pork sector actors willing to work together for their VCS. The new indicator set will be tested on a specific pork value chain, as it offers a challenging set of societal issues (animal welfare, environmental impacts at farm gate, inconvenience for local communities, major economic restructuring in France, and slaughtering/processing facilities in overcapacity (Monastyrnaya et al., 2017). Combining a literature review on sustainability assessment frameworks and a real world context example of a defined set of indicators, we propose a reflection on the metrics to be used for defining and monitoring the sustainability of a pork value chain. Section 3 outlines and comments existing frameworks and indicators for sustainability assessment. Section 4 focuses on contextualization in a pork value chain via the hotspots approach. Section 5 discusses the effective contribution of the framework. We wrap up with a conclusion on the underlying barriers and bottlenecks encountered.

2.1. *Defining an assessing framework of VCS*

The following section deals with the most common frameworks used in the scientific literature and in business practice to assess one or more dimensions of a product's or organization's sustainability. We examine the natures, perimeters and scopes of applications in order to emerge their potential contributions to a sustainability assessment of a food value chain, while understanding the limitations of such an exercise.

2.2. *Generic frameworks retained for our study*

Without claiming to be exhaustive, Table 1 groups different frameworks used to assess sustainability in the food sector. This synthesis proposes four categories of evaluation frameworks according to whether they are mono or multi criteria and whether they concern the entire life cycle of the system being evaluated or only one or a limited number of life cycle phases.

I/O frameworks are based on the work of Leontief (Leontief, 1986). Initially intended to establish the volume of financial exchanges between different categories of economic activities, they have since been extended to macro measurement of GHG emissions in the energy sector (Paloviita, 2003; Wiedmann, 2009) and in the food sector (Huppes et al., 2008). However, this approach is not adapted to measurement at value chain scale.

CSR is mainly focused on the social pillar of sustainability (Macombe et al., 2011). This political approach has been instrumentalized through international standard ISO 26000 in order to help companies and organizations reduce their externalities on both society and the environment. While CSR proposes a multi criteria framework, the assessment remains mostly social and its scope is centered on one organization or actor, even if data from suppliers can be included in reports through audits.

SLCA is a framework for assessing real and potential social and socio economic impacts throughout the product/services life cycle on the relevant actors (workers, local communities, consumers, etc.). The assessment requires system specific and generic data and differs from other social impact assessment methodologies by its purpose (product or service oriented) and application (the life cycle) (Andrews et al., 2000; Dreyer et al., 2010; Jørgensen et al., 2008).

CBA is an ex ante self assessment of a project to assess its relevance. Its use aims to promote an environmental policy by comparing the costs and benefits of a solution. In the framework of public policy, the aim is to promote individual well being (Harscoet, 2007). It is currently difficult to applying a value chain to the CBA valuation context.

MFA is a framework for systematic assessment of flows and stocks of materials in a studied system, whose perimeter is defined in space and time (Brunner and Rechberger, 2004). Linking the different steps of extraction, transformation, storage, use and disposal of a product, a material balance controls the inputs, stocks and outputs of the processes. This potentially interesting method is mostly used for decision support, management of resources, waste or environmental impacts, and circular economy studies, but it is not purposed to consider a lifecycle perspective.

LCA is a framework governed by the ISO 14040 standard to evaluate the environmental impacts of a product, process or service by taking into account all stages of its lifecycle, from extraction of raw materials through to end of life (ISO, 2006). The framework is based on an inventory of material and energy flows and it calculates environmental impacts such as global warming, eutrophication, depletion of natural resources, etc. LCA is multi step, multi criteria method based on an iterative cyclical approach.

LCC is a framework that sums all the costs generated during the

Table 1
Recap of major food-sector sustainability frameworks.

		Frameworks dedicated to one step of the life cycle	Framework addressing the whole product life cycle
Monocriteria frameworks	Environmental	• Material Flow Analysis (MFA) • Input/output (I/O) framework (based on GHG impacts)	• Life Cycle Assessment (LCA) • Carbon footprint (CFP) • Water footprint (WFP)
	Social	• Corporate social responsibility (CSR) • Social Hotspot Database (SHD)	• Social Life Cycle Assessment (SLCA) • Social assessment (UNEP/SETAC)
	Economic	• Cost-Benefit Analysis (CBA) • Input/output (I/O) frameworks (based on economics exchanges)	• Life Cycle Costing (LCC)
Multicriteria frameworks		• Multiple-Attribute Decision-Making (MADM) frameworks like MASC.	

whole lifecycle of a product/service for a given actor or group of actors. It differs from other of cost accounting methods by its object, the life cycle of a product or service, and by its purpose of meeting stakeholders' needs. LCC is a decision support to guide design choices for managers and product choices for buyers, and more generally to optimize the cost/quality ratio of a product/service (AFNOR, 2017; Woodward, 1997).

CFP and WFP are two subsets of Wackernagel and Rees' ecological footprint (Wackernagel and Rees, 1996), i.e. the land surface and water required to produce the resources used and assimilate the waste generated by a defined population. By extension, the footprint of a product or service can be calculated as the average surface area and resources needed for its entire life cycle.

The SHD has been developed on the basis of work by Catherine & Greg Benoît Norris (Benoit Norris et al., 2012). It gives an overview of social hotspots in product supply chains for 113 countries and 57 economic sectors. The database includes a comprehensive list of indicators on labor rights, health and safety, human rights, governance and community infrastructure. It provides a clear indication of potential social risks and hotspots for countries and economic sectors, but is based on national averages and does not give specific information for suppliers or products. Nevertheless, this database offers a decision making tool for managing an organization or a value chain (Benoît Norris et al., 2011; Benoît, 2010).

The example of MASC 2.0 is used to describe the case of sustainability specific MADM frameworks because it is agrifood oriented and very popular in French research communities. Developed by the French National Institute of Agricultural Research (INRA), it includes the three pillars of sustainability and is farm scale oriented (socio economic context). This framework is based on qualitative decision trees (DEXi framework; Bohanec, 2008) by querying two levels of criteria: (1) basic criteria (*cost effectiveness, work overload, phosphorus losses*); and (2) aggregated criteria located upstream of the basic criteria and which are informed by experts according to qualitative reasoning (*long term productive capacity, farmer expectations, societal expectations, pressure on resources, wildlife conservation*). MASC is intended for advisers or farmers to improve technical production paths.

2.3. *Specification of metrics for VCS*

Table 1 clearly shows that no one framework is suitable for overall sustainability evaluation of food value chains from farm production to consumer retail (the lifecycle/multicriteria cell is empty). The following section thus sets out to clarify the constraints to be taken into account to build metrics for agrifood value chain sustainability based on an assembly of the above described frameworks.

2.3.1. *Mono/multicriteria*

The interest of monocriteria frameworks is limited for our purpose. Multicriteria approaches are preferred when the problem is complex or has several, sometimes contradictory, objectives (Mardani et al., 2015). A multicriteria analysis aims to clarify a coherent family of differentiating elements for designing, justifying and transforming preferences within a decision making process. Monocriteria studies do not often reflect reality, and addressing certain problems with a single criterion can prove a hazardous exercise (Aouni and Laflamme, 2014), as any attempt to improve the sustainability performance of a food value chain via a monocriteria assessment (carbon footprint, water footprint) would lead to imperfect decisions or evaluations. Within our scope of study, we need to reconcile several aspects to integrate a triple bottom line of environmental, social, economic criteria.

Multicriteria indicators would be the ideal solution for sustainability evaluation in a food value chain.

2.3.2. *Single/multi actor*

Some frameworks are designed to analyze a single step of the lifecycle, for example a detailed analysis of a production site, with particular focus on working conditions or stakeholder wellbeing. They can focus on local impacts (like noise, air quality, biological disturbance, social acceptability) while lifecycle frameworks focus on global or regional impacts (climate change, acidification, photochemical oxidation, resource depletion). In the comprehensive approach to whole VCS we are interested in here, we need to take both the local and whole cycle aspects into account.

2.3.3. *Lifecycle thinking/non lifecycle thinking*

Life cycle thinking (LCT) frameworks focus on the impacts of a product or a service “from cradle to grave”. The frameworks developed in LCT associate modeling data that capture the impacts of the elements and sub elements of a system. Even for a single site study, the impacts calculated will not be limited to a production plant, for example, but will also take into account the impacts of producing the energy to heat the buildings. LCT frameworks like LCA prevent pollution transfers from one step of the product life cycle to another, from one geographical area to another, and/or from one ecosystem to another and from one impact category to another. SLCA has even been used in the literature to measure the social impacts of the agrifood sector (Busset et al., 2014; Delcour et al., 2014; Wangel, 2014; Yildirim, 2014).

The indicators used in these frameworks are standard and not contextualized. However, for the purposes of this study, we need to establish a combined set of both generic and specific indicators to report on situations and activities related to the economic, geographical and social location of the value chain. Three frameworks were retained for our pork value chain contextualization: (a) MASC (MADM specific frameworks), (b) CSR (generic and specific), and (c) LCA (generic). The combination of the three meets the needs identified for our analysis in terms of the characteristics of existing frameworks and their ability to measure the sustainability of a whole value chain, i.e.:

(1) To cover all three pillars of sustainability (environmental, economic, social);
(2) To be product/service lifecycle based;
(3) To span a whole value chain being multi actor.

3. Experimental case study of a food VCS

3.1. Data collection and model building

Section 3 concluded on the need to propose metrics to evaluate the sustainability performance of a whole value chain. To validate the feasibility and effectiveness of the approach, an experimenta tion was carried out in the context of an existing pork value chain in which the actors are already working together to improve the sustainability of their products and want to go further to improve the sustainability of the whole value chain (Monastyrnaya et al., 2017; Petit et al., 2017; Petit et al., 2017a, 2017b, Petit et al., 2016, 2015, 2014). There is an agreement between the upstream agri food cooperative and the downstream distribution cooperative to define specification standards on pig feed, care and living conditions.

This section aims to define a set of indicators that match the requirements established in Section 3 and that help to assess and monitor the sustainability performance of the whole value chain. In a joint management decision making perspective, the new metrics should serve to compare various alternatives in order to improve overall sustainability. We therefore need to measure trends and orientations rather than exact values.

The functional unit is the annual production of a pig farm in the form of cooked ham at the retailer gate. From a cradle to crave perspective, the system consists of five subsystems: weaning—fat tening, slaughterhouse, processing, storage, and distribution. Data were collected from two French cooperatives—one from an agri food including feed supply, pig farming, and the slaughterhouse; the other from a distribution cooperative including storage, dis tribution platform and retail (20 shops for a theoretical region as big as the Pays de la Loire in France). The sustainable hotspots of the value chain were expressed by interviews with these actors (10 guided structured interviews with value chain actors and 20 ex changes with different experts and stakeholders in the value chain). The economic data used are taken from publications by technical centres for experts in the profession. Complementary data were obtained from the Agri footprint LCA database (Netherlands) and contextualized for French pork production. Capital goods, cleaning products and packaging material for transportation were not included. Mass allocation was performed for a multi product sys tem. The LCA was conducted using SimaPro 8.0.5 software. We chose the ReCiPe 1.11 calculation method as it conventionally used in the agrifood sector. The indicators were selected in accordance with the interests declared by the actors interviewed.

Table 2 is a synthesis of identified hotspots. They are distributed by step of the lifecycle. Some hotspots are common to different stages of the lifecycle and therefore to many actors (i.e. water, en ergy, etc.). We will return to this aspect in the section discussion our results. The hotspots presented here are the result of the wishes expressed by the stakeholders interviewed without taking into account the restrictions related to data accessibility issues.

Combining LCA, SCR and MADM specific frameworks is an approach that respects the specifications output from Section 3 and allows us to fill in some of the impacts underestimated by the hotspots identified in Table 2. On the other hand, the lack of field data makes it impossible to propose indicators for reporting on certain hotspots. For the welfare of employees, for example, both on farm and throughout the value chain but particularly at the slaughterhouse, it would have been interesting to propose one or more measures of this welfare, but it was just not possible here. As the value chain actors interviewed did not have the indicator framework classification scheme during the interviews, they expressed the sustainability elements as they individually perceived them. Some of the terms used refer directly to an indi cator, others to a hotspot, or other sometimes even more generally to a whole sustainability pillar. For example, one interviewee said: "*Finally, we have a real coherence with the soul of the company. It is the impact of our activity on the local or global environment*". Our understanding and interpretation of this statement leads us to believe that all the company's employees are concerned about its impact on the environment, which is why we naturally used impact indicators derived from an LCA specific methodology (Recipe; Goedkoop et al., 2009) conventionally used in agrifood studies. However, other interviewees described “hotspots” more in terms of the pressure of effluents and their treatment on the environment or ecosystems. Through the contextualized experimentation, we built the set of indicators presented in Table 3. Column 1 inventories the indicators used to assess VCS. Column 2 links the indicator to the hotspot it qualifies. Column 3 highlights from which framework previously described in section 2 the indicator was adapted. Col umn 4 justifies how each indicator directly or indirectly matches the needs expressed in interviews with value chain experts. Col umn 5 gives further clarification on the linkages across different columns of the table. Finally, column 6 gives the nature of the performance measured according to the ‘DPSIR’ system (Smeets and Weterings, 1999). DPSIR stands for Driver Pressure State Impacts Responses and is described below Table 3. CSR stands for Corporate Social Responsibility, LCA stands for lifecycle assessment and MASC refers to a Multiple Attribute Decision Making frame work presented in Section 2.

The indicators from Table 3 can be distinguished by the nature of the performance they measure (dedicated last column). For the purposes of this study, we chose the DPSIR (*Drivers Pressures States Impacts Responses*) model adopted by the European

Table 2
Synthesis of identified hotspots.

Value chain step	Hotspots
1. Breeding	1.1 Biodiversity
	1.2 Pig performance
2. Weaning-fattening	2.1 Water
	2.2 Energy
	2.3 Pig feed
	2.4 Pig excretion
	2.5 Animal welfare
	2.6 Antimicrobial resistance
	2.7 Economic health
3. Slaughterhouse	3.1 Water
	3.2 Byproduct valorization
	3.3 Consumer information
	3.4 Worker welfare
4.Processing	4.1 Water
	4.2 Byproduct valorization
	4.3 Consumer information
	4.4 Worker welfare
5. Storage	5.1 Water
	5.2 Energy
	5.3 Relationship with stakeholders
	5.4 Healthy and affordable food
	5.5 Equal opportunities
	5.6 Consumer information
6. Distribution	6.1 Water
	6.2 Energy
	6.3 Relationship with stakeholders
	6.4 Healthy and affordable food
	6.5 Equal opportunities
	6.6 Consumer information

Table 3
Description of the selected set of indicators.

Indicator	Hotspot	From	Expert opinions from interviews	Comment/further explanation	DPSIR
Carcass pH	2.1	CSR	#Slaughterhouse director "There is an interest [for actors] to know that pH24 is representative of a certain level of quality" "We didn't wait for them to look after animal welfare"	The more the animal is stressed, the higher the acid pH value of the meat due to the production of lactic acid.	S
Max transport without pause	2.1	CSR	#Sustainable value chain Project Leader " [Transport between farm and slaughterhouse] Should we not shorten certain cycles, play on the positioning of certain slaughterhouses, or on our supply, on how to organize collection rounds, things like that"	The animal is stressed during transport	S
Localness		CSR	#Slaughterhouse director "On the social front, there is the will on the site to work on aspects tied to job pain points"	Value related to the local features of the value chain and products. Indicator expressed in terms of percentage of local cereals (region) in the pig diet	S
Farmer welfare	3.4	CSR	#Head of the French Pig Farming Agency "You can't kill the farmer"	In the absence of a quality indicator to describe the "wellness" hotspot, a qualitative global rating is applied on the basis of a survey	P
Employee welfare	3.4	CSR	#Plant Director "Employees think that their work is better valorized"		P
Biodiversity	1.1	CSR		Number of species included in the feeding recipe for pigs. In the absence of a good indicator, this one at least has the merit of addressing the issue and showing the value of describing this issue in future	S
Sensory evaluation score	5.4 6.4	CSR	#Marketing manager To come back, the consumer has to find another service with added value"	Study of a panel of consumers to assess perceived taste quality	S
5.4/6.4	5.4 6.4	CSR		Refers to the health benefits of a better omega 6/omega 3 ratio in our diet	S
GMO feed ratio/formula	20	CSR		Refers to the French rejection of GMOs, desire not to consume them, and therefore the perceived value of a food that does not contain them	S
Water losses after cooking	5.4 6.4	Masc		Study on finished product to describe the technological quality of the product and the related potential value	S
Additional cost paid to the farmer	2.7	Masc	#Slaughterhouse director "At one point, there is an added value generated for breeders to compensate for part of the incremental costs and part of the contribution to this sector. These extra costs, in discussion with [the other partners], can be redistributed"	An additional reward for the struggling breeder following the introduction of a new business model	S
Production valorization (loss rate)	3.2	CSR	#Head of the pig group "Concretely, it is making process changes, raising people's awareness, achieving recovery, consuming less"	Direct financial loss related to the non-marketing of the product equivalent	S
Lean muscle percentage	1.2	Masc	*Informal discussions*	Lean muscle percentage is directly used to calculate the compensation paid to the farmer. It is therefore a marker of the economic health of at least one link in the value chain	S
Waste and losses rate	2.7	CSR	*Informal discussions*	Indirect financial loss related to the implementation of a fictitious product (unnecessary operating cost)	S
Number of hires	2.7	Masc	#Head of the pig group "That day, he hired someone to be able to come with us"	Number of hires throughout the value chain, linked to introduction of a new scenario or business model	S
Added work	2.7	Masc	*Informal discussions*	Extra workhours for at least one value chain actor	S
Variation in labor cost	2.7	Masc	*Informal discussions*	Variation (positive or negative) of the overall cost of labor related to the introduction of a new scenario or business model	S
Short-term investment (€/t)	2.7	CSR	#Slaughterhouse director "It is necessary to implement ecological, social, societal aspects, not just compensate investment (economics)"	Short-term investments for the introduction of a new scenario or business model	I
Long-term investment (€/t)	2.7	CSR			I
Variation of cost-to-make	2.7	Masc	#Energy project manager "You consider the economic motivation, to boost the industrial framework. The challenge is to control the costs"	Change in manufacturing cost offset to tray	S

(*continued on next page*)

Table 3 (*continued*)

Indicator	Hotspot	From	Expert opinions from interviews	Comment/further explanation	DPSIR
Climate change	2.1	LCA	#Energy project manager Finally, we have a real coherence with the soul of the company, it is the impact of our activity on the local or global environment	Mid-point indicator used to describe hotspots (water, energy, pig waste). The terminology of the hotspots and that used by the interviewee rely more on pressure indicators but are actually impact indicators (Recipe framework)	I
Terrestrial acidif.	2.2	LCA			I
Water eutroph.	3.1	LCA			I
Human toxicity	4.1	LCA			I
Freshwater ecotox.	5.1	LCA			I
Marine ecotox.	5.2	LCA			I
Land uptake–agric.	6.1	LCA			I
Land uptake–urban.	6.2	LCA			I
Water depletion		LCA			I
Fossil-fuel depletion		LCA			I

Environment Agency to define how performance is measured in the frameworks considered in this article. The DPSIR model postulates that, in the chain of causal relations to explain society–environment interactions, some determinants or driving forces (Drivers D) condition and explain negative pressures (Pressures P) and positive responses (Responses R) on the society or the environment (Smeets and Weterings, 1999). These pressures (e.g. pollution) and responses (e.g. protected areas) influence the situation and state (State S) of the system components. The re sponses of system components are expressed as impacts (Impacts I). This model is typically applied to characterize the indicators used to treat different aspects of an environmental problem ("pressure indicator", "state indicator", etc.). Assigning an indicator to a given DPSIR element can prove a complex task, as the same indicator can be considered as D, P, S, I or R depending on the question for which it is mobilized.

4. Discussion

4.1. Fitness of the new metrics for the requirements

First we analyze the objectives we had set ourselves, before turning to the difficulties, value and limitations of such an approach.

Mono/multi-criteria: Our metrics tackle all three pillars of sustainability (environmental, economic and social) as required. The assessment is multicriteria/multi impact as set out at the end of part 2.

Mono/multi-site or actor: These metrics are as multi site as possible. However, some of the selected indicators are only pro vided for a single site because they illustrate a hotspot that cannot be ignored but is only measurable for a single/a few value chain actor(s). "*Animal welfare*", for example, concerns actors handling living pigs: the pig farmer, possibly the carrier, and the slaughter house. Some indicators reflect the characteristics of the final product and therefore its sustainability (e.g. "*Water losses after cooking*".

Life Cycle-Thinking: Data capture is on the life cycle, but the way the values are compiled is heterogeneous from a methodological point of view. Some data—the environmental indicators—are cu mulative values of impacts throughout the life cycle, whereas many of our socio economic indicators are specific to a life cycle phase. Others (such as waste) are also cumulative.

4.2. Nature of the performance measured

The selected indicators relate to both state (S) and impacts (I) because at the moment, the diversity of stakeholders and demands to be considered makes it impossible to translate all data in terms of impacts. For example, measuring the "omega 3" ratio (because it is a component known to be lacking in quantities for the good con sumer health) in the final product is possible, but translating it in terms of impact on consumer health is difficult if not impossible. This is also the reason why some indicator values need to be sys tematically minimized (impact indicators, typically environmental indicators) while others have a target value (state indicators, such as "*carcass* pH" that must be targeted as between 5.40 and 6.10). As most of the state indicators are social indicators, a large part of the data is either inexistent or inaccessible. The coexistence of in dicators that need to be minimized and others that need to be targeted is perfectly acceptable here, as the goal of these metrics is to contribute to a general improvement approach. The logic is different from that of LCA which always seeks to minimize impacts.

4.3. Different temporality and system boundaries for indicators

The three sustainability pillars do not refer to the same types and natures of indicators. The social component is often based on qualitative indicators which are limited in terms of possible ranges of variation and values (Rich et al., 2011), whereas the environmental component is based on quantitative indicators with infinite possible ranges of variation and values.

The time scales between the indicators are also variable (Lockie, 2006), as are the perimeters. For example, for the indicator chosen for “global warming” expressed via the Recipe framework in terms of “radiative forcing” (i.e. impact on the “energy balance of the coupled Earth/atmosphere system”), the reference unit is watts per square meter (W/m^2). The effects of climate change are felt around the world over hundreds of years, whereas the “welfare of the farmer” is measured at most to the scale of the worker's lifetime. The carcass pH indicator relates at most to the scale for a pig intended for slaughter, i.e. a few months. Long term issues need to be understood and considered in order to roundly define the sustainable performance of a value chain, but economic actors have day to day decisions and trade offs to make. Therefore, indicators that describe short term cycles also have to be taken into account. Concerning the geographic perimeters, there is a broad scale variability in the set of indicators proposed here. For example, an environmental indicator like “fossil fuel depletion” concerns the global planet while “transport duration” concerns a territory/region and “worker wellbeing” concerns a manufacturing site (Brent and Labuschagne, 2006).

4.4. Quality of the input data

It takes a large bulk of data to build such metrics, as seen in Loiseau's work on territorial environmental assessment (Loiseau et al., 2012). Furthermore, there are differences among the three sustainability pillars in terms of quality of available data.

For the environmental pillar, data related to the system flows and used to carry out an LCA can be accessed through specific computing tools and softwares that produce precise, specific and sensitive values for different alternative scenarios. For the economic pillar, data may also be available, even if confidentiality is a big issue for companies wanting to communicate accurate and good quality data. Uncertainty can also penalize the data (Lenzen, 2006). Nevertheless, some average values can still be found in available sources and databases (e.g. national accounting databases) in order to bridge the gaps. For the social pillar, there are databases available (https://socialhotspot.org/), but they are very expensive, and their perimeters do not match the requirements of the study tackled here as they are concerned with the GDP of a country, which is far divorced from a value chain (Falque et al., 2014). One option to find values anyway is to pick up averages from the available literature. Moreover, specific data (such as those produced by surveys, typically for *Wellbeing* indicators) is recorded over longer periods, and so the resulting variability/lack of precision makes it difficult to conduct a strictly computational manipulation in order to observe the effects of variations. Several complex causality phenomena are linked to these social values and their variations, and they are not readily observable to researchers, for example, in the same way as economic or environmental data. Social value data require a contextualized and commented reading of an indicator set in order to interpret their implications (Zamagni et al., 2015). The data issue is decisive: it is essential to develop more databases (Grießhammer et al., 2006; Jolliet et al., 2004; Meybeck and Redfern, 2014), and to implement tools and media to collect, process and share the data underpinning the indicators (Petrini and Pozzebon, 2009).

Another recommendation could be to increase the frequency and standardization of sensitivity analyzes of this type of multi criteria study to better qualify the input data and the consequences of their use on the conclusions of the model and the resulting decisions. Indeed, beyond the difficulty of collecting reliable data, the inherent variability involving both environmental and economic information should also be taken into account. To ensure results robustness of this type of study, despite the uncertainty associated with some inventory data and/or methodological assumptions, these sensitivity analyzes should come along each study. An interesting development of this article would be to propose a sensitivity analysis by pillar and to investigate on the one hand if significant differences exist between them and on the other hand, how these differences influence the conclusions of the study and the resulting decisions for different stakeholders according to their nature or function in the value chain.

4.5. Concordance of social aspects with other dimensions

Some studies have already highlighted the difficulties faced by a social impact study and the management of various perimeters related to social and environmental aspects. First, social impacts are not directly related to unit processes but rather to an organization's practices or how it behaves with its environment and its stakeholders. Matching up the different perimeters to carry out a study is a real challenge (Godard et al., 2013). Several authors (Dreyer et al., 2010) assert that indicators that are barely quantifiable tend to be made qualitative. Furthermore, data collection for modeling impacts is a complex process that introduces great uncertainty into the studies (Pelletier et al., 2007). However, the objective of social study and assessment is to provide reliable results that can inform decisions and facilitate understanding of phenomena (Garrido et al., 2016; Parent et al., 2010; Wu et al., 2015). The outputs, even quantitative, need to be unambiguous and to answer the right question. The ambition is therefore not to measure all the social aspects but to compare the potential impacts of alternatives in terms of their contribution to enhancing or degrading levels of individual and social wellbeing (Kloepffer, 2008; Klopffer, 2003).

Although it is argued that ISO 14044 on environmental issues may be applied to social LCA (Weidema, 2005), the approaches are still under standardized. They tend to focus on identified “*hotspots*” (Norris, 2014; Norris et al., 2014, 2011) or relationships between one problem and related phenomena. This warrants specific work, as in Feschet who proposed a classification of SLCA studies based on their legitimacy and the scope of impacts and indicators studied (Feschet, 2014). In line with Kruse (Kruse et al., 2009), who complements LCA with a socioeconomic framework but not until implementing indicators, we advocate adopting a combined top down and bottom up approach.

4.6. Genericity of the study

Even though the frameworks presented in this article are mostly generic (except for MASC, which we retained to illustrate the case of MADM frameworks), part of the indicators in the metrics proposed here was designed in the real world pig chain specific context but could nevertheless be extended to other animal/meat value chains (“*carcass* pH”, “*animal welfare*”, etc.). The information related to beef performance is already traced and communicated with greater precision than for pig performance, because beef based final products have higher added value and so beef value chains have been able to develop more advanced means of guaranteeing high perceived quality for consumers[59,60]. Even with lower added value, poultry value chains have welfare metrics, such as counting the number of leg injuries to express the fact that the animals fought hard or not and thus were over stressed or not (Bouvarel and Fortun Lamothe, 2013). It would have been inter esting to take into account the number of signs of fighting on pigs at the time they arrive at the slaughterhouse in order to report on their state of stress, but this kind of data is not yet available (actors in the chain are in the process of carrying out these studies). Our study is also transposable to animal value chains in neighboring countries. Even if country specific characteristics are inevitable, the better competitiveness of German and Spanish pigs does not pre clude the economic indicators discussed here from being relevant descriptors of value chain performance. And the environmental indicators we used are still relevant for those value chains (Nguyen et al., 2012).

5. Conclusion

This paper focuses on how sustainable assessment approaches and indicators can be mobilized for sustainability assessment in a food value chain, so that actors willing to work together can find ways to improve their overall sustainability. The hotspots approach supported by a series of interviews with actors in the pork value chain serves to instantiate the approach in order to highlight its limits.

This new conceptual framework for sustainability, which we anticipate as a useful starting point for the overall assessment of food value chains, sets the following requirements: (1) all three pillars of sustainability need to be covered (environmental, eco nomic and social); (2) the metrics need to be life cycle thinking based/sourced; (3) the metrics need to be indicators of status (S) or impact (I); and (4) the metrics need to be multi site due to the value chain level of analysis.

A reflection on metrics used to evaluate the sustainability of competing alternatives in order to highlight improvement paths is proposed, and the bottlenecks are identified. The adequacy of the new metrics is discussed, as well as the different temporality and system boundary constraints for the indicators, the quality of the input data needed, and the concordance of social aspects with other dimensions of sustainability. Finally, we underline the genericity of the study.

Today, these metrics reflect the sustainability of a food value chain as well as the limitations of difficulties encountered and discussed here. In a management context, the framework could allow food value chain decision makers to better position their sustainability (qualitatively and quantitatively). Because they encourage continuous improvement and collective reflection on sustainable food value chains, these new combined metrics should be adapted and developed to all types of food value chains in the future. Differentiated information should be provided on food products and their impacts on the environment and society, on other stakeholders, and on the value chain actors themselves.

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