A participatory, territory-rooted and change-oriented framework to assess the multi-criteria contribution of an agrifood value chain to sustainable development

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Abstract

Agrifood value chains (AVCs) can be powerful driving forces for sustainable development. Multi-criteria analysis is particularly useful for supporting decision making on improvement measures in AVCs. Methodological guidelines are needed to effectively integrate environmental and socio-economic assessment tools and indicators at this level. In this paper, we propose a participatory, territory-rooted and change-oriented framework. The framework is applied to analyse the contribution of the main local poultry AVC in Reunion Island to the sustainable development of the territory. The main stakeholders of the AVC participated in (i) identifying the key challenges facing the territory, (ii) selecting the corresponding appropriate assessment methods and indicators, (iii) defining the perimeter of the AVC and (iv) defining the improvement scenarios to be explored, v) providing data inventory, and vi) interpreting the results of the assessment. The environmental life cycle assessment (LCA) and the effect method, an economic cost-benefit method, were integrated in the framework. They were applied to the same AVC data inventory and used to assess the improvement scenarios. The indicators were spatialised to distinguish the impacts in the root territory from externalised impacts in the rest of the world. In the ecological dimension of the assessment, most of the effects linked to the AVC activities which threaten resources conservation and ecosystem health are externalised: 82% of environmental impacts occur outside Reunion Island. This is due to the island's dependence on foreign resources, i.e. fossil energy and raw materials used for livestock. In the socio-economic dimension, the employment created by the AVC is mainly local: 89% of jobs are created in Reunion Island thanks to local broiler production which mainly uses local services and processing facilities. "Improvement of on-farm eco-efficiency" was shown to be a mitigation option that would significantly affect the impacts of the AVC. Human and ecosystem health, and resources conservation would be improved by respectively +2.2, +9.8 and +4.8% outside Reunion Island. But the AVC industrial network and the community would also be negatively affected, by respectively -2.2 and -3.0%, in Reunion Island. This study underlines trade-offs between the ecological and the socio-economic dimensions and discusses methodological principles for the effective integration of socio-economic assessment methods with Environmental LCA.

Keywords: *Sustainable development, multi-criteria assessment, method integration, life cycle assessment, effect method, salient stakeholders, broiler supply chain, Reunion Island*

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Abstrak

Agrifood value chains/AVC (rantai nilai industri pangan) dapat menjadi kekuatan pendorong utama untuk pembangunan berkelanjutan. Analisis multi-kriteria sangat berguna untuk mendukung pengambilan keputusan tentang tindakan peningkatan dalam AVC. Pedoman metodologis diperlukan untuk mengintegrasikan alat dan indikator penilaian lingkungan dan sosial-ekonomi secara efektif di tingkat ini. Dalam makalah ini, kami mengusulkan kerangka kerja partisipatif, berbasis pada root territory dan berorientasi perubahan. Kerangka kerja ini diterapkan untuk menganalisis kontribusi AVC pada unggas lokal di Pulau Reunion terhadap pembangunan berkelanjutan wilayah tersebut. Para pemangku kepentingan utama AVC berpartisipasi dalam (i) mengidentifikasi tantangan utama yang dihadapi wilayah tersebut, (ii) memilih metode dan indikator penilaian yang sesuai, (iii) menetapkan batas AVC dan (iv) menentukan skenario perbaikan yang akan dilakukan, v) menyediakan inventaris data, dan vi) menafsirkan hasil penilaian. Penilaian siklus hidup lingkungan (life cycle assessment /LCA), metode dampak, dan metode biaya-manfaat ekonomi, diintegrasikan dalam kerangka kerja. AVC diterapkan pada inventaris data yang sama dan digunakan untuk menilai skenario peningkatan. Indikator spasial untuk membedakan dampak di root territory dari dampak eksternal di seluruh dunia. Dalam penilaian dimensi ekologis, sebagian besar dampak yang terkait dengan kegiatan AVC yang mengancam konservasi sumber daya dan kesehatan ekosistem dieksternalisasi sebesar: 82% dampak lingkungan terjadi di luar Pulau Reunion. Hal ini disebabkan oleh ketergantungan pulau itu pada impor sumber daya, misalnya energi fosil dan bahan baku yang digunakan untuk ternak. Dalam dimensi sosio-ekonomi, lapangan kerja yang diciptakan oleh AVC sebesar 89% menggunakan tenaga kerja lokal, lapangan kerja ini diciptakan di Pulau Reunion berkat produksi broiler lokal terutama menggunakan layanan dan fasilitas pemrosesan lokal. “Improvement of on-farm eco-efficiency (Peningkatan efisiensi lingkungan di lahan)” ditunjukkan sebagai opsi mitigasi yang secara signifikan akan mempengaruhi dampak AVC. Nilai untuk indikator kesehatan manusia, ekosistem, dan konservasi sumber daya akan ditingkatkan masing-masing sebesar +2.2, +9.8 dan +4.8% di luar Pulau Reunion. Tetapi jaringan industri AVC dan masyarakat juga akan terkena dampak negatif, masing-masing sebesar -2.2 dan -3.0%, di Pulau Reunion. Studi ini, menekankan kepada trade-off antara dimensi ekologis dan sosial ekonomi dan membahas prinsip-prinsip metodologis untuk integrasi efektif metode penilaian sosial-ekonomi dengan LCA Lingkungan.

Kata kunci: *Sustainable development, multi-criteria assessment, method integration, life cycle assessment, effect method, salient stakeholders, broiler supply chain, Reunion Island*

1. INTRODUCTION

Agrifood value chains (AVCs) can be powerful driving forces for sustainable development. They fulfil basic functions like ensuring food security, livelihoods (for rural populations), employment, and create economic values along value chains [1],[2]. On the other hand, AVCs can have major negative impacts on earth ecosystems (soil and water pollution, loss of biodiversity), climate (greenhouse gas emissions), resources depletion (fossil resources), and on human health (contaminated water and air) [3]. Changes to reduce environmental impacts can be made at different levels of the AVC. See for instance Gerber et al. [4], on reducing the contribution of the livestock sector to climate change.

The agro-industrial system is the main organisational model of AVCs in terms of the volume of food products sold [5]. This system tends to spatially separate consumers and agricultural production [6]. Today the cumulative distance between a product in the different steps in the AVC from production to delivery to the consumer can be trans-national or trans-continental. As a result, the people (consumers) who benefit from the first function provided by agriculture, food security, are no longer connected with main people (farmers) who produce the food and have major interactions with the environment [1]. However, in recent decades, a change has been observed in consumer awareness that takes the form of a preference for shorter food chains, i.e. within a territory [7]. This shift is reflected in the increasing number of direct sales channels, community-supported agricultural organisations, and the expansion of local and national labels [8]. These alternative organisational models generally symbolise values like equity, food safety, quality, traceability and low environmental impact [9]. A compromise is possible between the agro-industrial system and the alternative short integrated AVCs. It assumes a transition from pure agro-industrial systems to agro-industrial systems more anchored in the consumers' territory. But this transition faces two challenges: (i) the need for quantitative rational arguments to support the transition and to monitor progress in interactions between the AVC and the consumers' territory, and (ii) stakeholder empowerment and commitment. New frameworks are thus needed to analyse the complexity, to quantitatively assess the impacts of AVCs, and to help managers of private firms and policy makers to inform their decision making [10].

Many indicators, indices, methods and tools to assess sustainability can be found in the literature [11],[12]. Environmental life cycle assessment (LCA) has distinguished itself in a rich literature by its ability to provide a holistic assessment of a given AVC. It is recognised to be one of the most advanced methodologies with clear and proven methodological guidelines [13]. Several studies have been conducted to complete the ecological indicators provided by environmental LCA with socio-economic indicators to cover the different pillars of sustainable development and render the results more useful for decision making [14]. Multi-criteria (ecological and socio-economic) assessment is still an open research field at the AVC level [15],[16],[17]. Some emerging initiatives such as Value Chain Analysis for Development (VCA4D) [†] seek to assess the contribution of AVC to sustainable, inclusive growth and job creation. See for instance, works of Bennet et al. [18] analysing the beef AVC in Zimbabwe. However, as recalled by Jørgensen et al.,[19] and Petit et al., [17], there is no consensual framework for such an assessment of AVCs. Moreover, the methods were combined rather than integrated, as there is no consistency in data inventory between the environmental and the socio-economic dimensions [17],[14].

The present paper precisely proposes a multi-disciplinary framework aimed at effective integration of environmental LCA and the effect method. The effect method, developed by Chervel and Le Gall [20], is a cost-benefit analysis which uses input-output tables for socio-economic project appraisal. Based on the value added generated by the project, it is possible to characterise the redistribution of wealth to different firms within a territory, usually a country. When regional input-output tables are available, it is also possible to spatialise wealth distribution [21]. Wealth can be translated into jobs, tax and capital which are useful socio-economic indicators to complement the ecological indicators provided by the environmental LCA. The effective integration of these two methods is a methodological challenge as they originate from two different scientific disciplines: environmental LCA from environmental engineering and the effect method from economics.

Here, the framework is illustrated using a case study of a poultry meat AVC in a tropical island, Reunion Island, a French overseas department

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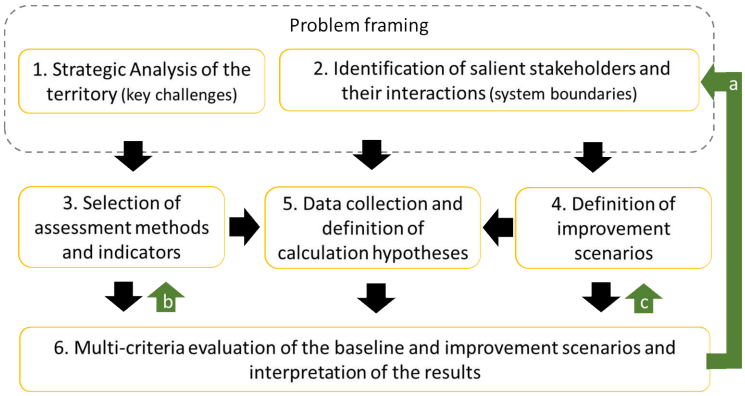

Figure 1. The six-step framework used to assess the contribution of an Agrifood Value Chain (AVC) to sustainable development (green arrows a,b and c indicate feedback loops)

located in the Indian Ocean close to Madagascar. Like in many isolated, narrow and densely populated territories, local decision makers have to make choices between low-cost food imports from agro-industrial systems versus more locally anchored food production systems that may generate more value locally. The poultry meat AVC is an interesting and complex study case because local production is based on large-scale imports of inputs (e.g. feed) and competes with meat imported from Europe. The study year we used was 2010. Given the local population's increasing concerns about environmental issues, mitigation measures up to 2020 were included in the scenarios. This paper discusses what lessons can be drawn from this case study for a broader use of the proposed framework, particularly in the tropics.

2. MATERIAL AND METHODS

2.1. The Proposed Methodological Framework

2.1.1. Six Main Steps

Inspired by the methodological guidelines of environmental LCA, the proposed framework has six main steps (Figure 1). The first two steps are framing the problem, i.e. performing a strategic analysis (step 1) to characterise the root territory and the environment of the AVC by considering both socio-economic and ecological challenges. It also involves identifying salient stakeholders and their interactions (step 2) to define the perimeter of the study system, i.e. the system boundaries. The methods and indicators are selected next (step 3) and the improvement scenarios are then defined (step 4). Step 5 is the equivalent of life cycle inventory in environmental LCA [13], during which data are collected and calculations made for both ecological and socio-economic analyses and for both the existing system and for the scenarios to be explored. Step 6 is the multi-criteria evaluation of the baseline and improvement scenarios and their interpretation.

2.1.2. A Participatory and Iterative Approach

The proposed framework was defined as iterative (feedback loops in Figure 1) and as being at the core of a participatory process [22].

The case study was carried out on the initiative of the focal firm. The focal firm marketed the final poultry products. It was a key decisional entity in the AVC we studied, as this food chain functioned on demand [23]. The focal firm convinced other AVC stakeholders to take part in meetings and relayed our requests for information and for the data required for the sustainability assessment.

The iterative participatory sustainability assessment process comprised six meetings over a three-year period (2011-2013). The two first meetings (year 1) aimed at framing the problem and making the initial selection of indicators (steps 1 to 3). The third meeting (year 1) aimed at defining the existing system (the AVC) and the improvement scenarios (steps 4 and 5). The first evaluation of the actual system (step 6) was presented at the fourth meeting (year 2), when discussions led to the re-evaluation of the salient stakeholders (feedback loop a to step 2) and the selected indicators (feedback loop b to step 3 in Figure 1). The two last meetings (year 3) mainly focussed on multi-criteria evaluation of the baseline and improvement scenarios (step 6). The re-definition of the improvement scenarios (feedback loop c to step 4 in Figure 1) was undertaken between the two last meetings.

The stakeholders involved included the managers of the focal firm and its salient, i.e. relevant, suppliers. See section 2.3 below for the definition of these stakeholders. The range of stakeholders involved was wider in the first and the last meeting as these two meetings included the people listed above plus representatives of several institutions involved in local agricultural governance.

Table 1. Results of the strategic analysis of Reunion Island territory (from the main characteristics of the root territory to key challenges) and resulting selected indicators.

Main characteristics of the root territory	Consequences for AVC functioning	Level of main impacts*	Key challenges	Impact indicators
Narrow territory (with limited agricultural land and high population density)	Dependence on imports, maritime transport	World	Ocean	Marine eutrophication and ecotoxicity
	High manure application rate on cultivated land	Territory	Soil	Soil acidification
	Dependence on imports, intensive crop production abroad	World	Rivers and groundwater tables Land	Freshwater eutrophication and ecotoxicity Terrestrial ecotoxicity
	Dependence on imports, employment abroad	Territory	Community	Job creation
	Proximity of industry & of the community	Territory	People	Formation of particulate matter
Mountainous relief	Small trucks required for the delivery of inputs and the collection of poultry products (higher particle emissions and high fuel consumption rates)	Territory	Humans	Formation of particulate matter
		World	Fossil resources	Fossil fuel depletion
Isolated territory	Coal - Fuel electricity based	Territory	Soil	Soil acidification
		Territory	People	Formation of particulate matter
		Territory	People	Human toxicity
		World	Fossil resources	Fossil fuel depletion
Tropical climate (with high temperatures)	High ventilation rate required on farms	Territory	Soil	Soil acidification
		Territory	People	Formation of particulate matter
Rapid transition from agriculture to tertiary sector	Local unemployment	Territory	Community	Job creation

* world = the rest of the world

2.2. Strategic Analysis of the Territory

A strategic analysis is needed to define the 'root territory', i.e. the territory in which the AVC mainly operates. The term 'territory' corresponds to a geographical area which seeks to aggregate intrinsic specificities at a certain scale to justify its uniqueness. According to Laganier et al. [24], these specificities are classified in three dimensions: identitarian, material and organizational. The goal of identifying a root territory and its specificities is to identify the key challenges facing the territory that need to be taken into consideration in the sustainability assessment.

In our case study, Reunion Island was defined as the root territory. It is the territory in which most salient stakeholders of the AVC are located, particularly the focal firm. It is also the home territory of the community supplied by the poultry AVC studied here. The main results of the strategic analysis of the Reunion Island territory concerning the supply of poultry meat are summarized in Table 1. It explained the connections between territorial characteristics in Reunion Island, the functioning of the poultry AVC and key challenges in the territory or in the rest of the world.

Employment in the local community, human health (linked to fuel consumption and particle emissions), dependence on fossil resources (energy in particular), and preservation of soils and fresh water were the main key challenges identified in collaboration with the stakeholders. Climate change was not mentioned, as the stakeholders' awareness of

this challenge in 2010 was not as high as today and climate change is slower in the southern hemisphere than the northern hemisphere due to fewer human activities and a higher proportion of oceans [25].

2.3. Characterization of Stakeholders and Their Interactions

The objective of this step is to define the system boundaries and to identify the stakeholders to be involved in the participatory process. The multiplicity and diversity of stakeholders and their interactions within the AVC calls for discernment to reduce complexity. In the following, we define several methods to select the salient stakeholders of a given AVC based on the degree of interactions among the stakeholders themselves and between the stakeholders and their environment. The methods we used differed depending on the socio-economic or ecological dimension.

For the socio-economic dimension, the method also differed depending on the type of stakeholders considered. With reference to the stakeholder typology proposed by [26],[27], three types of AVC stakeholders were distinguished: Suppliers, Competitors, and the Community (Figure 2).

2.3.1. Suppliers

AVC suppliers were defined beginning with the focal firm and moving upstream. The discriminatory criterion we used was the financial dependence (FD) of each supplier on its customers [28]. The FD rate is the customer's supply costs spent on the supplier divided by the total supplier's turnover. Moving upstream, the FD of each supplier was calculated iteratively at each step. This step was an iterative process because one supplier can supply more than one firm in the AVC (for instance in our case study, the firm which produced the poultry feed supplied both breeders and broiler farmers, Figure 2).

Several thresholds were used to classify suppliers in three categories: (i) collaborators ($FD \geq 70\%$), (ii) remaining salient suppliers ($70 > FD \geq 5\%$), and (ii) non-salient suppliers ($FD < 5\%$), i.e. more marginal suppliers (Appendix A). The collaborator category included the focal firm. All salient suppliers were assigned to a group of stakeholders, named AVC industrial network (AVCIN).

2.3.2. Competitors

Recent applications of game theory principles [29] in social LCA were useful for identifying salient competitors. We used a systematic competitive model as suggested by Lagarde and Macombe [30]. The range of competitors was limited to actors who supplied the same market with poultry meat as the main local AVC. The criteria used to classify salient and marginal competitors were the volumes of meat supplied to the territory, the market share in each local retail channel, and the capacity to expand in each retail channel in the next ten years (Appendix B).

2.3.3. Community

The community is an important component of the socio-economic environment of the AVC. The socio-economic health of the community is essential for a firm's longevity, and any loss of value in the system which could affect the community needs to be identified. The employees and customers of the focal firm, of the suppliers, or of any competitor, create value in the neighbouring community which could be affected by decisions taken at the AVC level. These people are included in the community. The salient community corresponds to the consumers and employees of the salient suppliers and competitors identified above.

For the ecological dimension, the criterion used was the relative importance of elementary flows (matter or energy consumption and pollutant emissions). To be consistent with the socio-economic analysis, we applied the same threshold (5%) to select the salient stakeholders who would have to be taken into consideration in the ecological assessment; i.e. stakeholders who contributed less than 5% of the environmental impacts were not considered as salient stakeholders and were excluded from the system boundaries (feedback loop a between steps 6 and 2, Figure 1).

Figure 2 shows that the common part of the system boundary (area in green) included most salient stakeholders of the socio-economic analysis. The common part corresponds to all the on-farm stakeholders and a large proportion of the pre-farm and the post-farm processes included in the ecological analysis. Among the 1,041 firms involved in the AVC studied here, the analysis concentrated on 124 firms that were salient for the ecological assessment and on 139 firms that were salient for the socio-economic assessment. The competitors and the community are specific salient stakeholders for the socio-economic analysis whereas the background processes (except local transport by truck) are specific salient stakeholders for the ecological analysis.

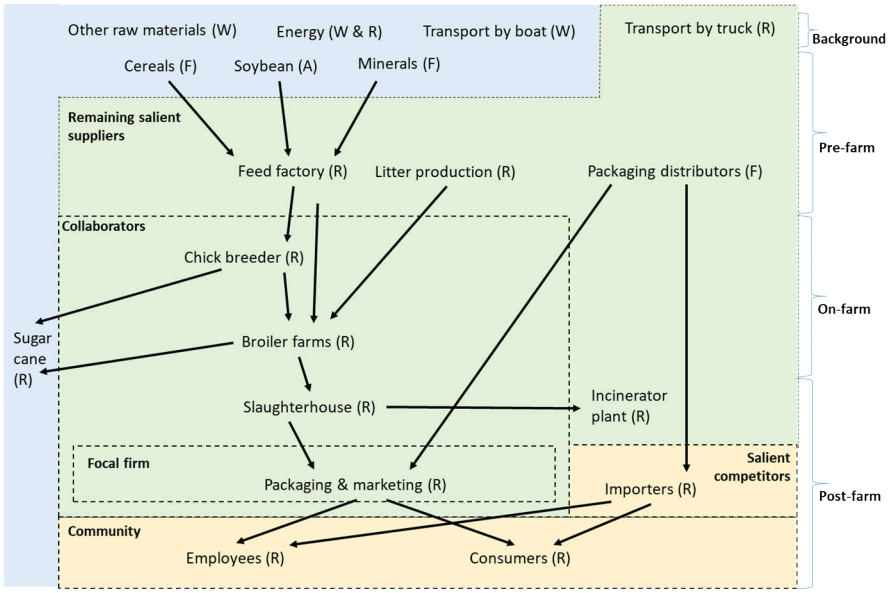

Figure 2: Flow diagram of the AVC and the system boundaries for the ecological assessment (areas in green and blue) and for the socio-economic assessment (areas in green and yellow). Arrows represent flows of goods and services between stakeholders (flows of raw materials, energy and transport are not represented for the sake of readability). The area in blue is specific to the ecological analysis and the area in yellow is specific to the socio-economic analysis. The area in green is common to the two dimensions. A location criterion is given in parenthesis for each stakeholder of the AVC (R: Reunion Island, W: the rest of the world, F: mainland France, A: Argentina).

2.4. Selection of Indicators and Methods for Multi-criteria Assessment

Methods and indicators were selected as representative of the key socio-economic and ecological challenges facing Reunion Island identified during the strategic analysis (see Table 1). Some were directly proposed by involved stakeholders, such as job creation and fossil fuel depletion; the others were first proposed by researchers and then validated by the stakeholders. All these indicators were calculated using the Environmental LCA (for the ecological dimension) and the effect method (for the socio-economic dimension). The main methodological choices are summarized below. Other methodological choices and hypotheses are described by Thévenot et al., [31],[32].

Job creation was the indicator chosen for the *socio-economic dimension* (Table 1). Employment generated by the AVC activities were spatialised (within the territory versus in the rest of the world) and was handled in three categories: (i) direct employment for collaborators, (ii) indirect employment for the remaining salient suppliers and the salient competitors, and (iii) employment induced, i.e. created for the community. These categories can be normalised as three challenges: employment in the AVC industrial network, competitors, and the community. Job units are expressed as national minimum wage equivalents (NMW-eq.), which corresponds to the annual minimum gross salary an employer is legally bound to pay its employees. In 2010, the French national minimum wage was €15,206/year.

Nine impact categories were identified for the *ecological dimension* in the strategic analysis (Table 1). The formation of particulate matter at the level of the island territory and human toxicity at the level of the rest of the world were the impact categories selected to represent effects on human health. At the level of the island territory, soil acidification was selected to represent the effect on ecosystem health. At the level of the rest of the world, fossil fuel depletion was selected for resources conservation, and freshwater ecotoxicity, freshwater eutrophication, marine ecotoxicity, marine eutrophication, and terrestrial ecotoxicity were selected to represent effects on ecosystem health. All these impacts were calculated using Simapro v 7.3.3 software [33]. The ReCiPe Midpoint and Endpoint method were used to characterise substances for each impact category and to normalise them into three challenges: resources conservation, ecosystem health, and human health [34]. Since the consumption patterns in Reunion Island are similar to those in Europe, we used the

weighting set "Europe ReCiPe H/H" in the ReCiPe method [35].

2.5. Definition of Explored Scenarios

The three explored scenarios had two components: context dynamics and improvement measures. The context dynamics were defined to simulate changes in the system under study, i.e. changes in the number and size of firms and in the flows between these firms. In our case study, the time horizon used for the analysis was ten years (2010-2020). The situation in 2010 was used as the baseline scenario ("2010"). The assumptions concerning changes in the context (scenario "2020") were expected population growth, the corresponding increase in the demand for poultry meat and changes in market shares among competitors. Poultry meat consumption per inhabitant in the preceding five-year period (2005-2010) was stable, so we assumed that consumption patterns would not change over the time horizon of the study. The share between the poultry AVC and its competitors was also assumed to remain unchanged over the study period, even when improvement measures were implemented.

Improvement measures were defined to make it possible to evaluate their effectiveness in progressing towards sustainability. These measures were implemented individually and in combination, the latter being the case in the scenario "2020_IS". In our case study, with a view to eco-labelling in the future, stakeholders wanted to explore three mitigation options that included equipment upgrading, improving farm eco-efficiency and reducing transport distance for inputs.

Equipment upgrading refers to (i) setting up a biogas plant to digest slaughterhouse wastes which were previously burned in an incinerator on Reunion Island; (ii) installing photovoltaic solar panels on the roof of the slaughterhouse.

Farm eco-efficiency refers to improving the feed consumption efficiency of broiler farms, as in 2010, farm performances varied widely [31].

Reduction of transport refers to the change in the country from which maize is imported. Maize represents more than 50% of the broilers' diet and is imported from Europe, i.e. from 10,000 km away, whereas closer countries in the Indian Ocean could supply Reunion Island. In this scenario, maize is imported from Mozambique instead of from Europe. It is assumed that both economic and political barriers have been overcome.

2.6. Data Collection

Data sources differed depending on the nature of the data (for socio-economic or ecological assessment) and the type of stakeholder (collaborators, remaining salient suppliers, the community or competitors).

2.6.1. Data Needed for the Socio-economic Impact Assessment

The revenue and expenditure account and the social report of each firm classified as a collaborator were used to calculate the *direct employment* generated by collaborators. The input-output tables for Reunion Island and France were used to calculate *indirect and induced employment* by other salient stakeholders (remaining salient suppliers, the community and competitors). These data were provided by the French national institute of statistics and economic studies [36],[37],[38]. An input-output table is an aggregation of all regional or national firms' accounts. It is based on Leontief Input-Output analysis [39]. The two input-output tables were modified to create new tables, from which the increase in local value and the intermediate imports for each activity sector can be deduced when there is an increase in final demand [40],[32]. For the community, the statistics on household consumption [41],[37] were broken down into modified input-output tables to calculate the effect on *induced employment* generated by the expenditure corresponding to the collaborators' and suppliers' employees' wages. Concerning competitors, the salient competitors' turnover and their market share were calculated using the estimated volumes of meat supplied and market prices (Appendix B). The market share equivalent to the meat volumes in competition with the AVC were broken down into the modified input-output tables to estimate employment that could be lost.

2.6.2. Data Needed to Assess the Environmental Impacts

Based on the collaborators' expenditure accounts, the same economic flows used for the socio-economic analysis were converted into elementary flows for the environmental LCA. Based on unit prices, economic flows were first converted into flows of goods and services and then combined with material flow accounting and air pollutant emission reports to calculate elementary flows. When available, local inventories (e.g. the energy mix in Reunion Island) or contextualised inventories from the literature (e.g. Agribalyse for animal feed) were used to provide conversion factors. The EcoInvent database was used as an alternative [42].

2.7. Scenarios

Mitigation options were based on ongoing projects. Most data were therefore collected in forecast reports from consultancy agencies. For the *Equipment upgrading* option, biogas and heat generated, which are intended to be used as a substitute for fuel in the currently oil-fired boiler system of the slaughterhouse, were consequently converted into fuel equivalents based on their respective lowest heating value. However, the equipment required to enable the plant to function would increase total electricity consumption. The solid waste produced by the digester was assumed to be used as fertilizer for sugar cane (the main agricultural land use in Reunion Island). The environmental impacts of the corresponding amount of mineral fertilizer avoided were credited back to the system [43]. The liquid waste from the digester was treated in the communal wastewater treatment plant. For the solar panels, the amount of electricity produced by the panel was deduced from the total amount of electricity consumed. The environmental amortization of the solar panel was taken into account. For the *Farm eco-efficiency* option, the feed consumption rate of inefficient broiler farms was reduced to the same level as that of the most efficient farms in the local farm population. The corresponding amount of ammonia gaseous emissions due to manure management was also reduced. The most efficient farms consume more electricity because they use ventilation equipment, so the amount of electricity consumed by inefficient farms was increased to that level. For the *reduction of transport* option, the new transport distance was evaluated from Beira port (Mozambique) to the main port in Reunion Island and technical operations in Mozambique were assessed using local average data for a large maize production area with high expansion potential [44]. Direct emissions from maize fields were estimated according to Nemecek and Kägi [45].

2.8. Multicriteria Evaluation of the Baseline and Improvement Scenarios

A simplified calculator was developed using Microsoft Office Excel software to facilitate its reuse by the focal firm. The first spreadsheet serves as the user interface. It contains a form allowing optional context variables (e.g. growth rates) and improvement measures (e.g. mitigation options like those cited here) to be configured for scenario analysis. The second spreadsheet is the shared inventory of economic and elementary flows. All the flows are spatially differentiated in the inventory by adding a location criterion. For instance, local transport by truck was allocated to Reunion Island (R in Figure 2) whereas boat transport was allocated to the rest of the world (W in Figure 2); and for local transport by truck, the impacts of fossil energy combustion were allocated to Reunion Island, whereas the impacts of its extraction and transport were allocated to the rest of the world. The Excel workbook is connected to a Microsoft Office Access database which contains conversion and characterization factors extracted from the EcoInvent database and the spreadsheet of embedded rates deduced from the input-output tables used for impact calculation and normalization. This calculator provided the indicators and figures in the Results section.

3. RESULTS

3.1. Impacts of the Actual AVC

3.1.1. Socio-economic Impacts

The spatial distribution of the value added created by the poultry AVC showed that 78% of the total value was shared by stakeholders in Reunion Island and 39% of the value added was redistributed within the local community. Thus, job creation mainly occurred in the root territory: Reunion Island (Figure 3). A total of 1,900 NMW equivalents was created in 2010 by the AVC activity and 89% of job creation occurred in Reunion Island. Respectively 100%, 72% and 87% of direct, indirect and induced jobs were created in Reunion Island. The remainder were created in the rest of the world, mainly in Europe and South America.

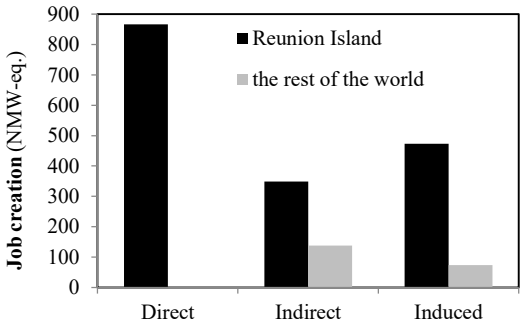

Figure 3. Spatial differentiation of socio-economic impacts of the main local poultry AVC (direct, indirect and induced job creation) in and outside Reunion Island in 2010.

3.1.2. Environmental Impacts

Figure 4 presents the normalized results of the environmental impacts of the AVC activities. The spatial differentiation of impacts showed that, except for soil acidification (SA) and the formation of particulate matter (FPM), most impacts occur outside the territory. These results confirmed that SA and FPM are major concerns for Reunion Island. The

main concerns for the rest of the world are freshwater ecotoxicity (FEC) and eutrophication (FE), terrestrial ecotoxicity (TE), marine ecotoxicity (MEC) and eutrophication (ME), human toxicity (HT), and fossil fuel depletion (FD), ranked in order of decreasing importance.

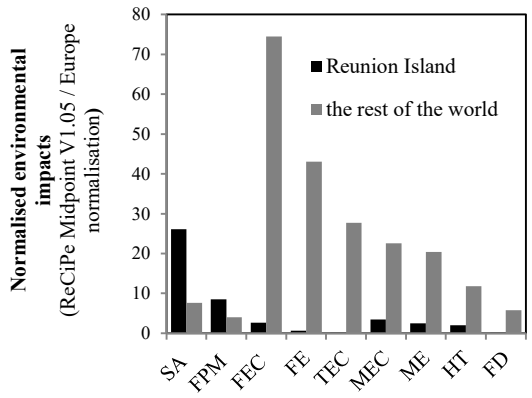

Figure 4. Normalisation and spatial differentiation of the environmental impacts of the main local poultry AVC in Reunion Island in 2010. SA: Soil acidification; FPM: Formation of particulate matter; FE: Freshwater eutrophication; FEC: Freshwater ecotoxicity; TE: Terrestrial ecotoxicity; MEC: Marine ecotoxicity; ME: Marine eutrophication; HT: Human toxicity; FD: Fossil fuel depletion.

Figure 5 shows the relative contribution of the suppliers to the total impact in the nine selected environmental impact categories. Only the six main contributors are differentiated on the vertical axis. The 118 remaining contributors are grouped under "other suppliers" (in grey).

At the Reunion Island level, only two suppliers (local poultry farmers and the local electricity supplier) contributed more than 96% to each selected impact category (formation of particulate matter FPM and soil acidification SA). In the case of the poultry farmers, ammonia emissions from poultry manure are precursors of the secondary particles which cause acidification when they are re-deposited on the soil and cause respiratory problems when they are inhaled [46]. Concerning the electricity power plant, direct emissions of primary particles discharged into the atmosphere are responsible for respiratory problems when inhaled.

At the level of the rest of the world, four suppliers (of electricity, maize, soybean meal and rice) contributed more than 68% to each selected impact category, except for fossil fuel depletion (FD) to which many suppliers contributed and the three main contributors contributed about 57% of the total impact. Concerning the supply of electricity, most impacts were due to pollutants emitted during the extraction of hard coal: phosphate for freshwater ecotoxicity, manganese for human toxicity and nickel for marine ecotoxicity. In the case of maize, soybean and rice, most impacts were caused by phosphate in the case of freshwater eutrophication, by chemical substances (pesticides) emitted into soil and water in the case of freshwater and marine ecotoxicity and human toxicity.

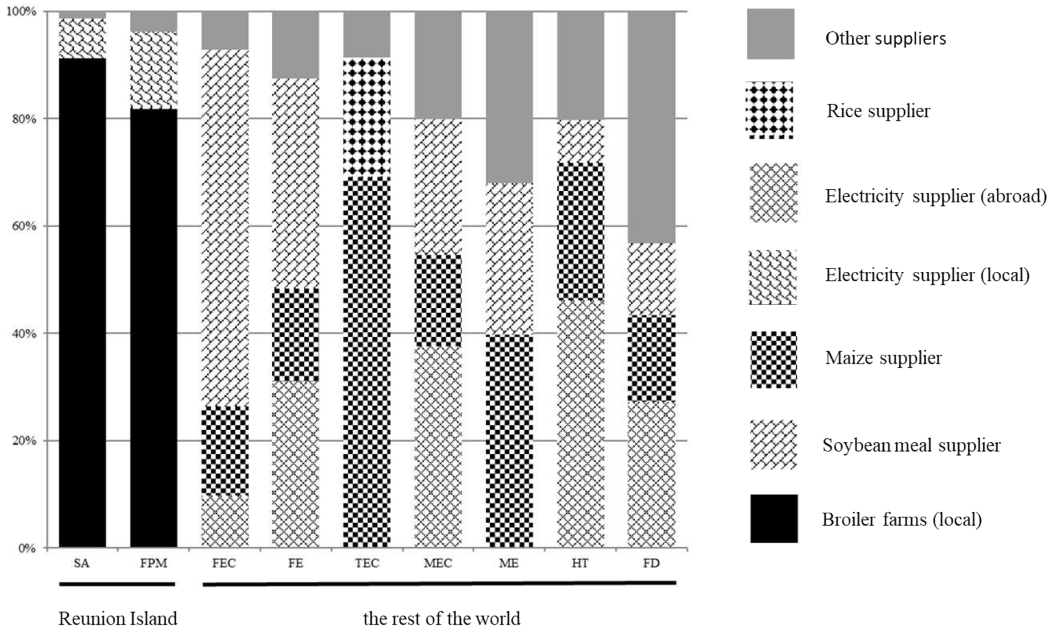

Figure 5. Relative contribution of the different suppliers to each environmental impact category in 2010 (only the six main contributors are differentiated on the vertical axis, the 118 other less important contributors are grouped under "other suppliers").

3.2. Changes in the Impacts of the Poultry AVC in the Next Ten Years

3.2.1. Impacts of Combined Implementation of Improvement Measures

Figure 6 and Figure 7 show changes in the impacts of the poultry AVC on the challenges selected in 2010 (scenario "2010"), in 2020 without improvement measures (scenario "2020") and in 2020 with improvement measures (scenario "2020_IS"). With no improvement measures, environmental impacts would increase by an average of +70%. With no mitigation measures, creation of jobs in the AVCIN would be +26% in Reunion Island and +70% in the rest of the world. In the community, the increase in job creation would be around +38% in Reunion Island and +61% in the rest of the world. If all three improvement measures were implemented together (scenario 2020_IS), environmental impacts would decrease by -4.6% to -16.1% depending on the category (with reference to scenario 2020, Figure 6 and Appendix C). Conversely, the mitigation measures would cause job losses both in the AVCIN and in the community. The losses would range from -2.2% in the AVCIN in Reunion Island to -16.2% in the AVCIN in the rest of the world. Improvement measures would have no impact on competitors due to the hypothesis on the dynamics of the share between the poultry AVC and its competitors (section 2.5).

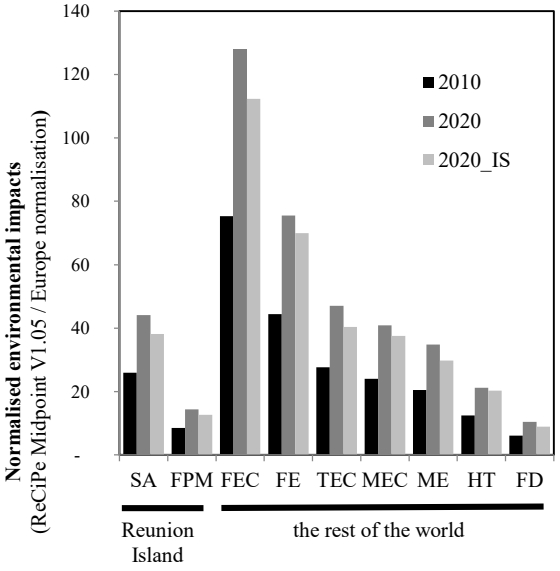

Figure 6. Normalisation and spatial differentiation of the environmental impacts of the main poultry AVC in Reunion Island in two prospective scenarios (2020 and 2020_IS) with reference to the existing AVC in the study year (2010).

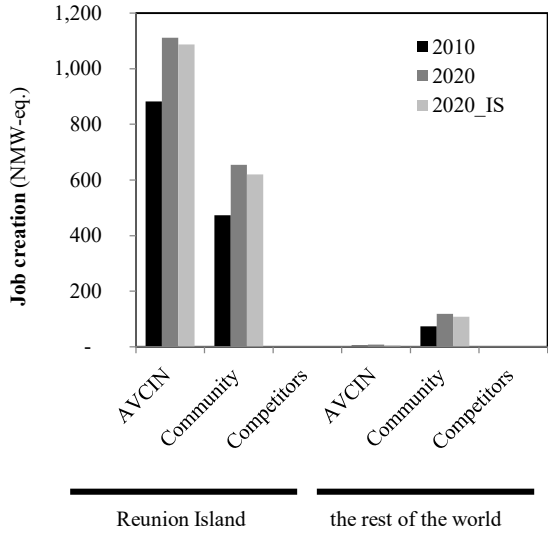

Figure 7. Spatial differentiation of the job creation within the AVC industrial network (AVCIN), the community and the competitors in two prospective scenarios (2020 and 2020_IS) with reference to the existing AVC in the study year (2010).

3.2.2. Impacts of Improvement Measures Implemented Separately

In Figure 8, the indicators listed in Figure 6 and Figure 7 are aggregated in the six challenges identified during the strategic analysis and defined at the "selection of indicators and methods" step (see section 2.3.). Figure 8 shows changes in the contribution of the AVC to sustainable development according to these six challenges if mitigation measures were implemented separately, with reference to 2020 (scenario "2020"). The bigger the area covered by the spider chart, the more the mitigation measure would increase the AVC's contribution to sustainable development. Improvement measures are analyzed here with respect to the importance of the resulting changes. Improving farm eco-efficiency would have the most consequences for the different challenges. It would positively affect ecosystem health both in Reunion Island and outside, human health mainly in Reunion Island and resource conservation mainly outside Reunion Island. This mitigation option would have the highest reduction score of all the environmental impact categories i.e., between -11% and -14.1% for TEC, SA, ME, FEC and FPM (appendix C). However, farm eco-efficiency would also negatively affect the AVCIN and the community, even more so outside Reunion Island. A reduction in the distance inputs are transported would have positive impacts on resource conservation, human health and ecosystem health (in decreasing order of importance) only outside Reunion Island. It would limit the impacts of

the AVC on marine ecotoxicity, eutrophication and fossil fuel depletion most (Appendix C). The impacts of the "reduction of transport" option on the AVCIN and the community would be very limited. Equipment upgrading would have very limited consequences for ecological challenges except for resource conservation outside Reunion Island. The community would also be affected by the equipment upgrading scenario inside Reunion Island and outside. The effects of the three improvement measures on competitors, i.e. importers, were null (see scenarios hypothesis, section 2.5).

4. DISCUSSION

In this section we discuss to what extent the methodological choices made in this study are generic and what lessons can be drawn from this case study for broader use of the proposed framework for other AVCs, particularly in the tropics.

4.1. What Made the Results Useful for Decision Making?

According to the stakeholders involved, three key points rendered the assessment results useful: (i) the spatial differentiation of results, (ii) the multi-criteria dimension of the analysis and (iii) the simplification of results through the aggregation of indicators.

The spatial differentiation of results underlines the distribution of the calculated impacts between territories (Reunion Island versus the rest of the world in our case study) and potential impact transfers between territories depending on the mitigation option. The results directly inform managers how their firm contributes (or not) to the development of the territory compared to other firms. In the case study reported here, most environmental impacts occurred outside the poultry production territory (on average 82% in all the impact categories, see Figure 4). Depending on the category, from two to five firms were responsible for 75% of the total impact (see Figure 5). These firms were generally grain traders who purchase raw materials (i.e. maize, soybean and rice) on the international market to produce livestock feed. Most environmental impacts of the AVC were due to the production and the transport of raw materials that were exchanged on the world market. Conversely, most socio-economic impacts occurred inside the poultry production territory. For the AVCIN and the community, respectively 99.5% and 86.5% of job creation occurred in Reunion Island (section 3.1.1) as the AVCIN and the community were mainly located in the root territory. Indeed, broiler production (i.e. farms) and, associated services and processing facilities (feed factory, chick breeders, slaughterhouse, meat packaging and marketing, etc.) are all based in Reunion Island (Figure 2).

The multi-criteria assessment underlined existing trade-offs between the socio-economic and ecological dimensions associated with the improvement measures. This confirms the difficulty involved in simultaneously improving sustainability in all dimensions [14]. For instance, several trade-offs would occur if the mitigation measure 'farm eco-efficiency' were adopted. The implementation of this mitigation option would lead to reduce environmental impacts (Appendix C) mainly because of the decrease in the consumption of feed by farms, the volume of meat produced being the same. The implementation of this mitigation option would negatively affect job creation because of the decrease in the consumption of goods and services in the vicinity of the firms that produce animal feed (Appendix C).

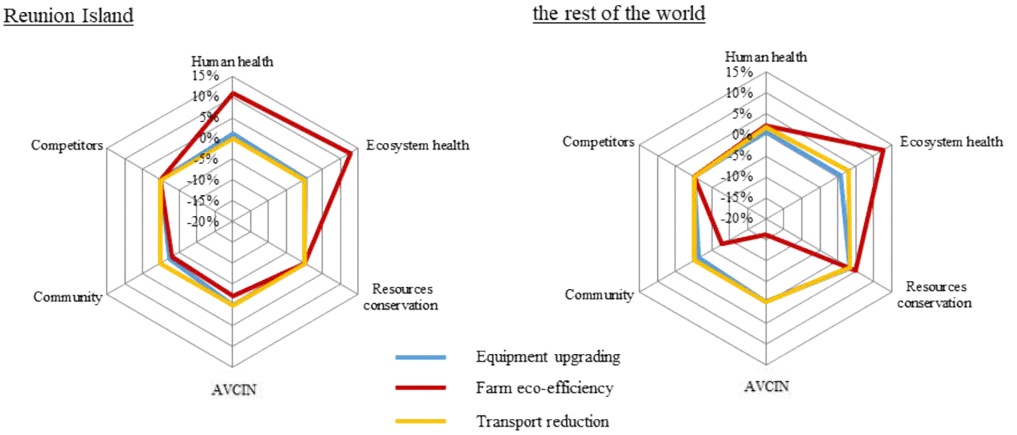

Figure 8. Changes in the contribution of the AVC to sustainable development in Reunion Island (left) and in the rest of the world (right) according to six challenges (AVCIN, community, competitors, human and ecosystem health, and resource conservation) for three different improvement measures by 2020 in comparison with 2020 with no measures taken.

The aggregation of the results is the subject of ongoing scientific debate [47],[48],[14]. In our study case, aggregation in six categories was undertaken to facilitate communication with a non-scientific audience. Aggregated results were more easily understood by managers than row impact categories, especially for the ecological dimension which is characterised by a large panel of impact categories. For instance, the radar chart in Figure 8 clearly showed that Farm eco-efficiency is the mitigation measure that would change AVC impacts most. Resources conservation and human and ecosystem health would be significantly improved by this measure. The community and the AVCIN would also be significantly, but negatively affected (section 3.2.2).

Thévenot provides an explanation of how the outputs of the assessment (the results and the tool) were used by the stakeholders for justifying European subsidies in Brussel, eco-labelling and prioritizing improvement measures in Reunion Island.

4.2. How Can the Determining Issue of Access to Data be Solved in Other Contexts?

This study demonstrates that the assessment of the multi-criteria contribution of an AVC to sustainable development involves a heavy burden of data collection and analysis (section 2.6). Data availability is the main limitation to the broader use of the proposed framework to assess other AVCs around the world.

In our study case, the application of the framework was facilitated by certain specificities of the AVC and territory. The narrowness and insularity of the territory, Reunion Island, facilitated the definition of the challenges to be met. Likewise, the identification of salient stakeholders of the AVC was easier since most steps, from feed factoring to sale of the finished product, took place in the same territory. In more globalized AVC, the relationships between producers and suppliers are more anonymous and ephemeral [49]. This may considerably complicate the identification of salient stakeholders.

In the present study, we had access to a regional input-output table which meant we were able to calculate results for specific sites. Input-output tables are available for most countries around the world, but there could be more uncertainties in developing countries. Indeed, international accounting standards are still not applied everywhere, given the difficulty involved in collecting and aggregating the data required to construct such accounts [50]. Moreover, input-output tables are rarely available at the sub-national level (except for European ultra-peripheral territories like Reunion Island) and there may be major inequalities and disparities between neighboring territories in each country. The regional input-output tables have been applied to sub-national geographic units since the 1950s [51] but this requires the collection of considerable additional data [52], which explains why it is not widely used.

The detailed production-expenditure accounts of all the local firms of the AVC were important sources of data for our assessment. The poultry AVC we studied is vertically integrated and well organized thanks to a clear division of tasks and to the support of an inter-professional association [23]. This pattern and the resulting clear communication between firms considerably facilitated access to these data in this study. Moreover, the accuracy of the accounts made it possible to cross-check the data sources provided by firms (expenditure accounts) with data provided by their suppliers (production accounts) and hence to check the coherence of data and to reduce uncertainty. Informal AVCs based on low-input systems are common in developing countries [53]. For instance, most fresh milk distribution networks around towns in West Africa are supplied by many small dairy collectors linked to an even larger number of dairy farmers with small herds and very variable farming practices [54]. Conducting a data inventory on this type of food system is challenging because of the lack of quantitative data. An alternative option would be to conduct wide surveys in collaboration with the many heterogeneous stakeholders. But data uncertainty increases when an assessment is based on data provided by expert judgment [55]. The participation of stakeholders of the AVC, including farmers in the case of informal AVCs, in the whole assessment process (see section 2.6) may be one way to reduce uncertainty [56],[15].

4.3. Are Other Ways to Conduct the Participatory Process Possible?

The framework assumes the active involvement of salient stakeholders in data collection to increase the quality and reliability of the inventory data and the definition of the scenarios. The participation of the main stakeholders of the AVC is also seen as a key way to incorporate their values and interests in the analysis [56],[15], and to facilitate appropriation of research results by the stakeholders [57],[14], and hence to increase the chances that the AVC will evolve. This study confirmed these points and, in addition, that the appropriation of assessment results by practitioners can rely on the construction of a simplified calculator with and for users (section 2.7), as argued by Guerin-Schneider et al. [57].

This study also showed that all six steps of the framework can be discussed with stakeholders. Each step enabled a significant exchange of knowledge

between scientists and practitioners, i.e. mainly firm managers in our case study. The iterative dimension of the approach ensures that the results of one step can lead back to the previous step and to the redefinition of previous methodological choices. For instance, in this case study, the presentation of assessment results led to redefinition of the selected assessment indicators and of scenarios explored (see double arrows in Figure 1; section 2.1).

In this study, the stakeholders involved in the entire assessment process were mainly AVC stakeholders, i.e. members of private firms, because we decided to concentrate on people who make decisions concerning possible changes within the AVC. The procedure for the selection of salient stakeholders at the problem framing stage (section 2.3) offers the opportunity to identify the key stakeholder who has most influence on the functioning and impacts of the AVC.

In our case study, the focal firm was a key stakeholder who played a key role in the participatory process. The focal firm's involvement at the very beginning of the assessment, its interest in the study and its motivation were keys to the success of the participatory process. It played a determining role in the large-scale involvement of stakeholders in the assessment process (see section 2.1). For future studies, special attention should be paid to identifying this key stakeholder. It is at the end of the chain when AVC functions on demand like in our case [23], but this key decisional entity may be located further up the chain in the case of top-down driven AVCs.

Including less obvious decisional entities in the participatory process, like the community (e.g. consumers) and salient competitors (not done in this study), may improve the quality of problem framing (steps 1 and 2) and communication on improvement initiative of the AVC.

4.4. What Are the General Lessons That Can be Drawn for Future Integration of the Methods?

This study explored the possible integration of Environmental LCA and the effect method. Some general lessons can be drawn from this experience for future integration of quantitative calculation methods. These lessons are summarized in the four principles of the framework proposed in this paper. First, the calculation procedure must incorporate the effects which occur along the whole AVC, as defined when the system boundaries are drawn. Second, the calculation procedure must be based on the strength of relationships between stakeholders and between stakeholders and the environment. Third, the calculation procedure must allow impact spatialization to distinguish between impacts within the territory and impacts in the rest of the world. Fourth, it is preferable that the chosen methods are compatible with scenarios analysis to provide a dynamic view of the AVC and its impacts. These four principles were defined with reference to advances in Environmental LCA.

For environmental LCA, the term "life cycle" refers to the notion that a holistic assessment requires the assessment of raw material production, manufacture, distribution, use and disposal including all intermediary transport steps necessary for or caused by the product's existence along an AVC. These different steps (or processes) generally correspond to different stakeholders. Similarly, the socio-economic evaluation by the effect method consists in calculating the value added generated by a project for all stakeholders of the territory concerned: the investor firm(s) (i.e. the firm(s) where the project is implemented), its (their) employees, other connected firms, public authorities, the state, etc. Consequently, the effect method systematically includes the AVC stakeholders in its analysis and calculations, but, like for the environmental LCA, in a second step, the most salient stakeholders have to be selected. For this purpose, the concepts of system boundaries and cut-off criteria was extended to the socio-economic assessment. In the proposed framework, the salient stakeholders are selected according to the same criteria. The salient stakeholders are those with the strongest interactions with the environment and with other stakeholders for the ecological and socio-economic dimension, respectively [58]. The cut-off criteria differed for each dimension: economic flows (e.g. value added) and market share for the socio-economic dimension and elementary flows (i.e. matter or energy consumption and pollutant emissions) for the ecological dimension (section 2.3). Additional concepts from social LCA (game theory, systematic competitive model [30]) were also considered for incorporation in the analysis of stakeholders who are not directly connected to the AVC by economic flows (e.g. the competitors, section 2.3. and Appendix B). Resulting system boundaries differed between the dimensions evaluated (section 2.3). At first sight, this could be considered as a limit to the integration of methods but, the socio-economic and the ecological subsystems are fundamentally different, justifying two different boundaries. This is consistent with the conclusions of Petit et al. [17] and Godard et al. [59].

Method integration can go further. Despite the fact the two assessment methods focus on different types of interactions (economic flows and elementary flows), this study proved that the same AVC inventory can be shared for the assessment of the two

dimensions. Economic flows between AVC firms used to calculate job creation, were transformed into elementary flows occurring along the AVC (section 2.4). This ensures the consistency of the comparison of ecological and socio-economic indicators and their dynamics when scenarios are explored (section 3.2.2). Job creation was the indicator chosen in this study. But more economic indicators like value added (i.e. wealth) distribution [21], tax and capital can also be provided by the effect method and may be more relevant in other contexts. The lack of quantitative methods to assess "pure" social indicators [60] like equity or solidarity limits the number of socio-economic indicators that can be incorporated in multicriteria assessment. For instance, in this study, nine environmental impact categories, versus one socio-economic impact category were considered (section 2.4). Social LCA is the subject of great expectations with respect to new additional social indicators, but Social LCA is still under development [61], and today should be considered as a complementary approach to environmental LCA, involving a different approach to life cycle thinking, which also questions method integration [62],[63].

The third key principle of the framework is the integration of spatial variability in the assessment by using a territorial approach instead of standard site-generic assessment. Spatialization helps distinguish impacts within a territory from impacts in other territories, when considering the transfer of impacts to other territories [64]. Spatialization can also provide a more complete representation of the complexity of a given geographical area (multi-functionality, a system evolving with stakeholder strategies) [65],[66]. The existence of regional input-output tables, i.e. at the level of the root-territory enabled the spatialization of socio-economic impacts of the AVC and its further development. The territory does not necessarily refer to a region or a country but rather seeks to establish a level that is differentiated from the rest of the world [24]. As mentioned in section 4.2, it is extremely likely that this type of data is not available in other contexts, which would considerably complicate the spatialization of indicators provided by the effect method.

Like for Environmental LCA, method integration implies making an analytical choice between a descriptive assessment (i.e. assessing the contribution of one particular way of fulfilling a certain function) and a change-oriented assessment (i.e. addressing the changes caused by a modification from or to one particular way of fulfilling a certain function) [67]. The effect method is basically a project appraisal method, it consists of an economic analysis and calculation procedure designed to compare two situations: one with and one without a project. This method is thus compatible with both descriptive and change-oriented assessment. As illustrated in this study, the second approach is preferable because it provides the opportunity to involve stakeholders in a positive and constructive dynamics (section 4.3) but it also requires significantly more data to define change scenarios (section 4.2).

5. CONCLUSION

A framework designed to evaluate the contribution of AVCs to sustainable development was applied to the poultry meat AVC in Reunion Island. The salient stakeholders of the AVC were involved in the six-step assessment process including: (i) the identification of the key challenges facing the territory, (ii) the selection of corresponding appropriate assessment methods and indicators, (iii) the definition of the AVC to be studied, i.e. the strategic system, (iv) the definition of the improvement scenarios to be explored, (v) data collection, and (vi) the interpretation of the results of the assessment. Our results showed that the AVC externalizes most of its environmental impacts (due to its strong dependence on imports of raw materials), whereas it internalizes most of its contribution to socio-economic impacts (due to the fact that the poultry production and the main associated services and processing facilities are located in Reunion Island). Analysis of the scenarios provided a dynamic view of the future of the AVC and insights into the potential effectiveness of some mitigation options proposed by the stakeholders. The improvement in farm eco-efficiency was the measure that would change the impacts of the AVC the most.

Apart from the participatory approach which was chosen to increase the quality and reliability of the assessment, four principles of the framework can be considered generally applicable to identify good candidate methods to use in combination with environmental LCA. First, the calculation procedure must incorporate effects that occur along the whole AVC, as defined when the system boundaries are drawn. Second, the calculation procedure must be based on the strength of relationships (e.g. economic or elementary flows) among stakeholders, and between stakeholders and the environment of the AVC. Third, the calculation procedure must allow impact spatialization to distinguish impacts within the territory from impacts in the rest of the world. Fourth, it is preferable that the chosen methods are compatible with scenarios analysis, i.e. provide a dynamic view of the AVC and its interactions with its socio-economic and ecological environment. These are the four principles of the framework proposed in this paper.

Further studies studying different food chains in a broader context are needed to test the genericity of the framework. The fact that the poultry AVC studied here is vertically integrated and deeply rooted in a single narrow island territory, and that it supplies a European ultra-peripheral territory facilitated data collection. Studying informal AVCs like those most frequently encountered in the tropics, will require adapting data inventory methods.

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Appendix A – The salient suppliers of the poultry AVC in Reunion Island

The table below shows the distribution of suppliers as a function of their financial dependence on their customers. A total of 1,041 suppliers were involved in economic flows with the AVC studied here, of whom 125 were classified as collaborators, 14 as remaining salient suppliers and the remaining 902 suppliers were classified as non-salient suppliers and thus not included in the socio-economic assessment. The "collaborators" category included stakeholders involved in the final transit of the product: the feed factory, the chick breeder, the broiler farm cooperative, the broiler farms, the slaughterhouse where the product is processed in Reunion Island, and the marketing division. The most important remaining salient suppliers included the transporters (by truck), the incinerator plant, and packaging distributors.

Type of supplier	Non-salient suppliers*	Remaining salient suppliers	Collaborators	All suppliers
Financial dependence (%)	[0; 5]	[5; 70]	[70; 100]	Total
Number of suppliers	902	14	125	1,041
Share	86.6%	1.3%	12.0%	100.0%

* not included in the socio-economic assessment

Appendix B – The salient competitors of the poultry AVC in Reunion Island

The table below provides the main information used to analyse competition on the poultry meat market in Reunion Island. The market was sized based on declared production by competitors, and was double checked using both top down (evaluation based on the needs of the population) and bottom up approaches (evaluation based on the sales of feed and sales of chicks). There are only two feed production factories and two chick producers on Reunion Island, so we were able to accurately estimate the volumes of meat supplied.

Poultry supplier		Importers	Local AVC n°1 (the case study)	Local AVC n°2	Local AVC n°3	Local AVC n°4	Independent producers
Volume of meat produced	Tonnes	17,920	8,609	670	50	250	3,596
Proportion of the production as broilers*	%	100	100	100	0	10	100
Retail channel (%)	Supermarkets	100	80	10	100	100	0
	Butchers	0	0	86	0	0	0
	CHR	0	11	2	0	0	0
	Mass catering	0	9	0	0	0	0
	Direct sales	0	0	2	0	0	100
Volume of meat in competition with AVC n° 1	tonnes	17,920	0	67	0	25	0
Market share	%	67	32	<1	0	<1	0
Potential for expansion in the next 10 years (2020)	tonnes	Unlimited	+14,617	+5,000	0	0	Unknown

*The rest of the production concerns other poultry species: ducks, guinea fowl, turkeys, etc.

The analysis revealed three types of poultry meat suppliers in Reunion Island: importers, local AVCs (n = 4) and small independent producers (n = ~200). These suppliers used five retail channels to sell their products: supermarkets, butcher shops, cafés - hotels – restaurants (CHR), the mass catering sector (hospitals, canteens and other collective establishments) and direct sales. The only salient competitor was importers. Importers compete with the local AVC n°1 because 100% of their imports are broiler products and 100% of their volumes are sold via supermarkets, the main retail channel of the AVC in our case study. The other competitors mainly produce other poultry species (local AVCs n°3 and 4) or sell their products through different retail channels from those used by AVC n°1 (local AVCs n°2 and 4). In the reference situation in 2010, importers supplied 17.9 10^3 tonnes of product in competition with the local AVC n°1 studied.

Appendix C – Detailed changes in the different impact categories by 2020 if improvement measures are implemented separately or combined compared with 2020 with no improvement measures

The table below lists changes in the different impact categories and indicators by 2020 if mitigation options are implemented separately or combined in comparison with 2020 with no improvement measures.

Level	Stake	Impact Category	Equipment upgrading	Farm eco-efficiency	Reduction of transport	All measures (2020_IS)
Reunion Island	Ecosystem health	SA	-0.5%	-13.0%	0.0%	-13.5%
	Human health	FPM	-1.1%	-11.0%	0.0%	-12.1%
	AVCIN*	Job creation	0.0%	-2.2%	0.0%	-2.2%
	Community	Job creation	-2.3%	-3.0%	0.0%	-5.3%
	Competitors	Job creation	0.0%	0.0%	0.0%	0.0%
The rest of the world	Ecosystem health	FEC	-0.2%	-11.7%	-0.4%	-12.2%
		FE	-0.3%	-6.3%	-1.0%	-7.5%
		TEC	0.0%	-14.1%	0.0%	-14.2%
		MEC	-0.6%	-4.5%	-3.6%	-8.2%
		ME	-0.9%	-12.4%	-3.4%	-16.1%
	Human health	HT	-0.7%	-2.2%	-2.0%	-4.6%
	Resource conservation	FD	-3.5%	-4.8%	-3.2%	-11.0%
	AVCIN*	Job creation	0.0%	-16.2%	0.0%	-16.2%
	Community	Job creation	-1.3%	-7.9%	0.0%	-9.2%
	Competitors	Job creation	0.0%	0.0%	0.0%	0.0%

*AVCIN: Agrifood Value Chain Industrial Network