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Designing Sustainable Production and Distribution Scenarios for the Beef and Pork Supply Chains in Brazil

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ABSTRACT

Due to the intensive use of natural resources in food production in Brazil and the consequent air and water pollution, sustainable production is high on the agenda of businesses and policy makers. This paper designs sustainable production and distribution scenarios for the beef and pork supply chains in Brazil, covering Planet, People and Profit aspects. A case study design is employed in a multi-phase qualitative approach, consisting of two rounds of interviews to pursue the final design of six feasible scenarios for the beef and pork chains. Three sustainable production and distribution scenarios for beef are designed: *intensification, local production and sustainable operations* and *integrated land use*, and three for pork: *integration of animal and crop production, sophistication* and *balanced sustainability*.

The core improvements that can be extracted from the scenarios are: increased chain collaboration, information sharing in the chain, and governmental involvement in the Brazilian beef and pork supply chains. A major value of the paper lays in the three-phase methodology set-up. This paper will also contribute to the debate on sustainable improvements feasible in these Brazilian food chains.

Keywords. sustainability, beef, pork, supply chain, supply chain management, Brazil, scenario development

1 Introduction

It has been forecast that in 20 years the world population will have increased by 3 billion people, many belonging to the middle class. In the context of the huge challenge of feeding the future population, sustainability emerges as a top concern in the agendas of all the countries involved. "Sustainable development has been defined as meeting the needs of the present without compromising the ability of future generations to meet their needs" (Baldwin, 2009). In this research, the concept of sustainable development embraces three essential aspects (called '3P areas: profit-planet-people' of sustainability): economic (avoid imbalances), environmental (maintain biodiversity, atmospheric stability, etc.) and social (fair distribution and opportunities, etc.) (Harris, 2003).

An interesting case for research into sustainable food production is Latin America (LA). The farmers in Latin America are facing enormous obstacles in accessing European markets. The rate of production that is meant to sustain the requirements of the marketplaces and the peculiar production systems in Latin America involves environmental, social and economic problems for society, due to the intensive use of natural resources and the consequent air and water pollution, and ecological diseases (Hillstorm & Collier, 2004; Da Silva *et al.*, 2013). This paper will focus on two commodities in the largest country of the continent: pork and beef from Brazil.

Beef and pork chain sustainability issues

Brazil is facing increased competition in the global beef market. The major issues expressed in the literature studying the Brazilian beef chains are as follows: limited development of production, technical barriers, effective introduction of beef products from Brazil into the world economy (e.g. Europe marketplaces), food health, the exploitation of renewable resources, assurance of social welfare (human and animal), quality and safety of the final product (free from residues), land use expansion (especially in the forestland adjacent to the Amazon forest), and the greenhouse gas (GHG) emissions from production and transportation (Euclides Filho, 2004; Cederberg et al., 2009).

In the Brazilian pork chain typical sustainability issues are: manure management at the farm, animal welfare, meat quality and safety (e.g. use of antibiotics and subsequent residues), rural community issues (e.g. fair incomes) and environmental burdens. Further issues concern the use of resources and services (water usage, energy usage, etc.), soil and catchment health (reuse of by-product nutrients, etc.), climate change (managing gas emissions, renewable energy, climate variance, etc.), and community interactions (facilities impacts, relationships with the community, etc.) (Honeyman, 1996; Australian Pork Limited, 2008).

These issues call for an integrated approach that addresses all the three areas of sustainability.

The purpose of this study is *to design sustainable production and distribution scenarios for pork and beef in Brazil, where sustainable practices can be defined for these two food chains*.

A qualitative multi-phase methodology has been adopted, which delivers sustainable production and distribution scenarios for food supply chains, as guidelines for the chain agents. Given the differences in the production system and supply chain structure between the pork and beef chains, different sustainability issues and different sustainability scenarios are expected as outcomes of this study.

In light of this, the paper aims to answer to the following research questions:

- which sustainability indicators (economic, environmental and social) are best suited to assess the sustainability of the beef and pork supply chains?
- what are the most suitable scenarios (sets of sustainable practices) for farmers and actors of the two supply chains of pork and beef in Brazil to employ in order to manage sustainable development?
- what is the current sustainability level of the pork and beef supply chains in Brazil?
- which sustainability scenarios are feasible, and what are the sustainability improvement options that, starting from a certain level of sustainability, will lead to a future desired level of sustainability in these chains?

The remainder of this paper is organised as follows: first, the developed methodology is described; second, the literature review is presented; third, the three phases of the methodology are applied to the beef and pork chains in Brazil: i) the identification of 3P sustainability indicators, ii) the definition of improvement options for sustainability, iii) the final design of the sustainable production and distribution scenarios.

2 Methodology

The research was broken down into three phases (see Figure 1).

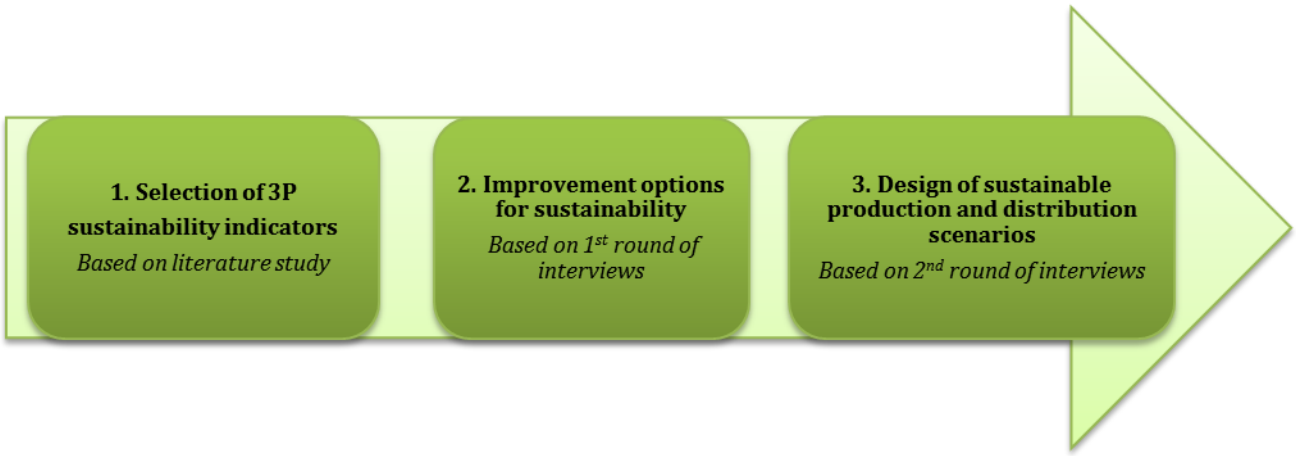


Figure 1. The three phases of this study (**bold** text refers to the deliverable, *italics* to the methodology used).

Phase 1: selection of 3P sustainability indicators

As displayed in Figure 1, an in-depth literature review was conducted in order to select a set of sustainability indicators that are suitable for this study. Fourteen major studies were selected, in particular review studies on sustainability indicators.

Phase 2: selection of improvement options for sustainability in beef and pork supply chains

Eleven interviews were carried out with key experts on sustainable pork and beef supply chains in Europe and Latin America, to: (i) select key indicators derived from the literature study in phase 1, (ii) identify sustainable improvement options (i.e. that address sustainability problems in the beef and pork chains), and (iii) identify business practices where concrete interventions take place.

Phase 3: the design of sustainable production and distribution scenarios

At first, in phase 3 four criteria were used with the purpose of turning the 'improvement options' of phase 2 into *sustainable production and distribution scenarios*. These criteria are: 1) select improvement options that address more than one sustainability indicator; 2) consider the number of times that the improvement option has been mentioned by different respondents; 3) consider the number of sustainability indicators addressed by the improvement option.

In total six scenarios were designed: 3 for the pork sector and 3 for the beef sector.

Next, these scenarios were further specified after the *second round of interviews* was carried out. Fourteen experts were approached to: (i) validate the scenarios selected in terms of feasibility of implementation and sustainable improvement; (ii) assess the sustainability of each scenario (using 5-points Likert scales for each of the thirteen sustainability indicators); and (iii) detail the practices in the scenarios into concrete actions (to support the step of detailing via literature).

Sources, methods and data analysis

The secondary data sources were mostly web-based, in the form of official reports, databanks and websites (e.g. FAO data: FAOSTAT and US department of agriculture: USDA-FAS). The primary data were collected through semi-structured interviews with experts in sustainability, the pork sector and the beef sector in Brazil, mostly from Brazilian Research Institutes and the network of the EU-7th Framework SALSA project, including Wageningen University. Twenty-five interviews were conducted in total, eleven in the first round and fourteen in the second round. Three interviewees were approached for both rounds of interviews.

The primary data gathered through the first and the second round of interviews were analysed using frameworks based on the literature study (i.e. indicator, practice and improvement options tables). These enabled the researchers to systematically analyse the data collected during the interviews and to frame as much information as possible without missing relevant data.

The choice of employing both the triangulation of methods and sources, and using frameworks to harmonise the analysis of the data collected preserves the *reliability* and *internal validity* of this research.

In the following section the originality of this study in the panorama of the sustainable Supply Chain Management (SCM) literature is introduced. Then, the three research phases are broken down into: i) the selection of the 3P sustainability indicators, ii) the selection of the improvement options for sustainability, iii) the design of the sustainable production and distribution scenarios for beef and pork.

3 The 3P Sustainability Indicators

The following literature related to indicators of sustainability in food supply chains, with special attention to case studies from Brazil has been considered (see Table 2).

Table 1.
Literature examined.

Literature on indicators of sustainability in a SC	Literature on indicators of sustainability in an SC (case studies from Brazil)	
Eurostat, 2011;	Carpentier *et al.*, 2001;	Stein & de Lange, 2007;
Unilever, 2010;	Muchagata & Brown, 2003;	Thaler & Holden, 2007;
OECD, 2001;	Peterson & Gerrish, 1995;	Pan & Kinsey, 2002;
Callens & Tyteca, 1999;	Vendramini *et al.*, 2007;	De Greef & Casabianca, 2008;
Epstein & Roy, 2011;	WSPA, 2012;	Q-Pork Chains, 2012;
Hutchins & Sutherland, 2008;	Fenley *et al.,* 2007;	Miele, 2011;
Nickolaou & Tsalis, 2013;	Cederberg *et al.*, 2009;	De Barcellos *et al.,* 2011;
Figge *et al.*, 2002a;	Grandin & Gallo, 2007;	Domingues *et al.*, 2013;
Willard, 2005;	OIE, 2011;	Embrapa, 2012;
Epstein & Wisner, 2001;	EU, 2013;	Bengtsson, 2009;
Figge *et al.*, 2002b;	IFAD, 2010Silveira, 1999;	Wallmann, 2006;
Bonneau *et al.*, 2011;	Tilman *et al.*, 2002;	Khachatourians, 1998;
Edwards *et al.*, 2008;	Pacheco *et al.*, 2012;	Vicari, 2012;
Verdecho *et al.*, 2012	Qi *et al.*, 2005;	OIE, 2011;
Meuwissen *et al.*, 2013;		USDA–FSIS, 2013.

This paper aims to build scenarios for sustainable production in beef and pork chains in Brazil. For this purpose, a scenario is defined as a comprehensive and integrated set of sustainability practices that might be applied in the investigated chains. Literature analysis shows that the state-of-the-art literature on the development of sustainability scenarios for beef and pork supply chains is at an early stage. Indeed, from an investigation of the existing literature, a limited number of attempts to design qualitative methodologies for scenario building in food chains have been pursued. One example is Caputo et al. (2014), which looks at resource use through the food supply chains in Northern Italy, in order to design sustainable scenarios following the Life Cycle Assessment (LCA) approach. Many studies take up the implementation of LCA and energy analyses to model sustainability scenarios that optimise integrated sustainability measures (the 3P areas are often referred to as a useful combination of sustainability indicators). However, there is no evidence of the existence in the literature of a methodology that provides sustainability scenarios for beef and pork chains, and certainly not related to these chains in Brazil. The relevance of this paper is contained in the contribution that this research represents for the scientific community engaged in building a theory on sustainable chains and testing it on food chains.

3.1 Selection of the sustainability indicators

Phase 1 of this research aimed at the definition of a coherent set of sustainability indicators based on the literature. The majority of studies selected provide taxonomies of indicators, based on in-depth literature and case study research. Indicators should be based on their suitability to assess the sustainability of supply chains according to the 3P areas (Profit, People, Planet, or economic, social and environmental). Accordingly, fourteen relevant studies were selected from the literature (Table 3). It is important to note that out of these fourteen studies, therefore out of the fourteen taxonomies of sustainability indicators proposed, a further and final selection of sustainability indicators is made through interviews with experts in both chains ("first round of interviews'" in figure 1). This final set of 3P sustainability indicators was chosen according to: (i) the number of times the sustainability indicator was mentioned by the experts, and (ii) the fit to the 3P areas. Table 3 frames the fourteen studies selected from the available literature. It shows the author of the study, the 3P areas involved, and the sustainability indicators.

Table 2.

The fourteen studies. From left to right: the author, the sustainability tool, the 3P area, and the sustainability indicators. (* some authors only reflect on main categories of indicators - 3P -, without further specification)

Author	Categories of sustainability (3P areas)	Sustainability indicators
Eurostat (2011)	Climate change and energy	GHG emissions, Energy dependence
	Sustainable transport	Modal split of freight transport
	Natural resources	Land use
Unilever (2010)	Environmental	Reduction of land use, Soil health improvement per hectare, Livelihoods per farmer, Amount of nitrogen lost in the environment (N lost), Amount of GHG emitted from cropping
OECD (2001)	Environmental	Air quality, Water resources, Energy resources, Biodiversity
	Economic	Income distribution, Produced assets, Technological change, Financial assets
	Human capital	Stock of human capital, Investment in human capital, Depreciation of human capital
Callens and Tyteca (1999)	Economic	Short term economic, Long-term economic effects
	Social	Short-term social, Long-term social effects
	Ecological	Short-term ecological, Long-term ecological effects
Epstein and Roy (2001)	Economic Social Environmental	*
Hutchins and Sutherland (2008)	Social	Gender equality, Labour equity, Healthcare
Nikolaou and Tsalis (2013)	Environmental	Recyclability, Reusability, Energy consumption, Energy sources, Fresh water use, Water reuse, Use of recycled material, Standardisation, Disassemblability, By-products, By-products reuse, Defects, Production waste, Biodegradable products, Size of the packaging, Sorting, Fuel consumption recovery
Figge *et al.* (2002a)	Environmental	Emissions, Waste, Material input/material intensity, Energy intensity, Noise and vibrations, Waste heat, Radiation, Direct interventions on nature and landscape
Willard (2005)	Economic Environmental Social	
Epstein and Wisner (2001)	Economic growth and employment	Economic growth, Social investment, Employment
	Social progress	Education and training
	Effective protection of the environment	Climate change, Air pollution, Transport, Land use
Figge *et al.* (2002b)	Environmental	Emissions, Waste, Material input and intensity, Energy intensity, Noise and vibrations, Land use
Bonneau *et al.* (2011)	Economic	Not specified
	Environmental	Manure management
	Animal welfare	Mortality
Edwards *et al.* (2008)	Economic	Economic viability, Independence, Transferability, Efficiency
	Animal welfare	Welfare quality programme
Meuwissen *et al.* (2013)	Environmental	Global warming, Primary energy use, Water deprivation, Land use
	Economic	Profitability, Volatility
	Social	Feed safety, Working conditions, Employability, Animal welfare, Food quality, Food safety

Table 4 shows the final selection of the sustainability indicators, related to the three sustainability dimensions, used for this study: i) economic indicators (income distribution, profitability, employment, and economic growth), ii) social indicators (gender equality, animal welfare, mortality, food quality and food safety), and iii) environmental indicators (GHG emissions, energy dependence, land use and water resources). Each of the sustainability indicators selected from the fourteen studies in Table 3 brings about sustainability measures providing numerical information about each indicator.

Table 3.
The final selection of the sustainability indicators in the 3P areas, and the corresponding measures.

Sustainability area (3P's)	Sustainability indicator (from Table 3)	Sustainability measure
Economic (**P = Profit**)	1. Income distribution	1a. Gini coefficients
	2. Profitability	2a. Profits 2b. Sales 2c. ROI 2d. Cash flow
	3. Employment	3a. Company turnover 3b. Jobs created
	4. Economic growth	4a. Number of full-time equivalent employees
Social (**P= People**)	5. Gender equality	5a. Ratio of average female wage to male wage
	6. Animal welfare	6a. Farmers score "worst, neutral, best" situation
	7. Mortality	7a. Mortality rates (%) as % of birth to weaning, post-weaning, fattening, weaning to slaughter, birth to slaughter, sows
	8. Food quality	8a. 7-point Likert scale
	9. Food safety	9a. 7-point Likert scale
Environmental (**P = Planet**)	10. GHG emissions	10a. Projections of GHG emissions 10b. Global surface average temperature 10c. GHG indicator 10d. % of suppliers with ISO 14001 certification or equivalent
	11. Energy dependence	11a. Electricity generated from renewable resources 11b. Energy consumption by fuel 11c. Implicit tax rate on energy 11d. Total energy consumption in each phase
	12. Land use	12a. Forest trees damaged by defoliation, 12b. (Hectares used/average local yield suppliers)-(Hectares used/average yield local country)
	13. Water resources	13a. Intensity of water use=abstractions/renewable resources 13b. Quantity of fresh water that is consumed during the manufacturing of a product

3.3 Improvement options for sustainability

In the second phase of the research, interviews were conducted with experts to make the final selection of indicators and to identify *improvement options* for sustainability for the beef and pork supply chains in Brazil. Improvement options identified for the beef chain include, among others: *intensification of the production system, integrated land use, renewal of the transportation infrastructure, no trading with less strict countries, the use of the agrosilvopastoral system, the exploitation of local product marketing.* For the Brazilian pork chains, some of the many improvement options for sustainability are: *integration of animal and crop production, local meat processing and local raw material purchasing, energy neutrality, and the use of feed sources not in competition with human consumption.*

4 Design of scenarios of sustainable production and distribution

In phase 3 of the research the resulting *improvement options* for sustainability, substantiated by the semi-structured interviews, have been turned into sustainable production and distribution *scenarios* using four selection criteria (see figure 2). The idea was to design scenarios that could feasibly be implemented in Brazil. These scenarios have been detailed in the "second round of interviews round" (see figure 1). The criteria that have been used for the selection are prioritised as follows:

Figure 2. The four criteria for the selection of the scenarios.

The four abovementioned criteria have been applied to the improvement options, and the outcome consists of six sustainable production and distribution scenarios. Each different scenario involves groups of sustainability practices. These sustainability practices support the discussions on the sustainable message raised by each scenario and enclose the core idea of where in the chain the intervention should be prioritised.

An overview of all the scenarios is summarised in Table 5 Appendix 1.

4.1 The six scenarios for beef and pork

4.1.1 Sustainable production and distribution scenarios for beef supply chains

As anticipated, the three **beef sustainability scenarios** that have been selected are the following: *intensification, local production and sustainable operations,* and *integrated land use*.

- ***Intensification*** of beef production will be extensively described in section 5.1.
- The ***local production and sustainable operations*** scenario for the beef Brazilian supply chains involves a number of implementable sustainable practices including improvements in 'local sourcing and operations' and improvements in 'sustainable transport and handling'. *Local sourcing and operations* involve: local meat slaughtering, local meat processing, and local feedstuff supply. S*ustainable transport and handling* encompasses: sustainable transport, expansion of the transportation network, improvement in animal welfare legislation, improvement of education concerning the relationship between animal welfare and meat quality, and payment according to meat quality.
- The ***integrated land use*** scenario for the Brazilian beef supply chains involves a number of implementable sustainable practices that range from 'farmland improvements' and 'chain-wide improvements' to 'governance improvements'. Among *farmland improvements,* the most important sustainable practices are: nutrient recycling, improvement of research on mixed beef production systems, improvement of research on sustainable production technical developments, the use of balanced production systems, improvement of grazing techniques, and intensification of the feed regimes. Among the *chain-wide improvements*, the sustainable practices are: increased differentiation in quality by introducing more labour-intensive and quality-enhancing production processes, performance of toxicological integrative studies on agrosilvopastoral systems, ensuring optimal conditions for animal transport, and investment in local roads and agroindustry. The *governance improvements* encompass: support to farmers to increase their profitability, government supported infrastructure investments, subsidies for local production, monitoring systems especially for organic production, fair trade initiatives and awareness campaigns in China and India, more sustainability-oriented regulations, the establishment of a worldwide quality and sustainability standard, and higher levels of regulation.

4.1.2 Sustainable production and distribution scenarios for pork supply chains

The three pork sustainability scenarios selected are: *integration of animal and crop production, sophistication* and *balanced sustainability*.

- The ***integration of animal and crop production*** scenario for the Brazilian pork supply chains involves a number of implementable sustainable practices, grouped in: 'manure management and meat traceability', and 'alternative feed and technical solutions'. Among the *manure management and meat traceability* improvements, some practices are paramount: nutrient recycle, investment in biodigesters to process manure into energy and fertilisers, and investment in meat quality and traceability. The *alternative feed and technical solutions* include:

use of animal feed not in competition with human consumption, use of decision support systems (DSS) to optimise the nutritional value of feed ingredients, and the use of feed-print models.

- The ***sophistication*** scenario will be extensively described in section 5.2.
- The ***balanced sustainability*** scenario for the pork Brazilian supply chains involves the following groups of sustainable practices: 'energy neutrality improvements'*, and* 'wellness and sanitary improvements'. *Energy neutrality* improvements include biogas investments to make energy for feed mills. The *wellness and sanitary improvements* encompasses the following sustainable practices: more animal friendly supply chain operations, investment in a monitoring system for residue management, minimisation of the risk of development of microbe resistance in humans, the establishment of new sustainability standards, and campaigns to inform consumers and increase pork consumption.

To conclude the description of the results, the two most advocated (by the experts) sustainability scenarios have been chosen to be looked at in more detail: *intensification* (beef chains) and *sophistication* (pork chains). While for beef the predominance of the extensive production system is endangering the landscape and biodiversity both through the high GHG emissions and overgrazing of pastures, for pork the main sustainability issues regard the nature of bulk commodities that it represents. As a result, the intensification of beef production and the sophistication of pork production represent valuable starting points from which strategically programming of sustainable improvements can start.

Additionally, the assessment of both sustainability scenarios is presented. Accordingly, the two scenarios receive thirteen sustainability scores each.

5 Zooming in: intensification and sophistication

As described in the methodology (phase 3), practices in the scenarios from (i) the literature review and (ii) the second round of interviews have been combined to describe the sustainability scenarios. For each of the scenarios, the sustainability assessment (radar plot with thirteen sustainability indicators) is provided and compared to the assessment of the general beef and pork chains in Brazil. Each indicator is measured on a 5-point scale, related to the average score for that indicator for each scenario, across all the respondents. The comparison shows the potential benefit of implementing the scenarios.

5.1 'Intensification' of the beef production system

The most important insight is the presence of two alternatives for the intensification of the production system: the daily supplement of concentrates or fodder, and the confinement of animals in paddocks or feedlots. These alternatives influence the successive practices that are needed to make intensified production systems work.

The following three sections describe the three main categories of improvement options to make the beef production chain more intensive: *improvement of farm and land management*, *production efficiency*, and *tradability improvements*.

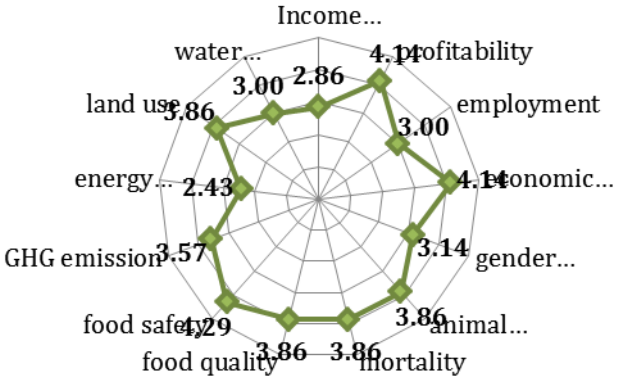
Summarised illustration of: *Intensification*		
Categories of sustainability interventions	**Sustainable practices involved**	**Sustainability assessment: From the current level of sustainability of beef chains (upper plot) to the sustainability level after implementation of the scenario (lower plot)**
Improvement of farm and land management	Fortification of the grass Nutrient recycling Use of decision support systems (DSS)	
Production efficiency	Optimisation of animal slaughter age Improved feeding techniques Genetic improvement Efficiency action plan at the farm	
Tradability improvements	Animal welfare considerations HACCP system requirement Pay price according to meat quality Electronic identification Requirement of a monitoring system for food safety Documentation requirement at the farm Compliance to carcass certification schemes	
According to the lower radar plot, income distribution, animal welfare, food quality (+0.86), profitability (+1.14), food safety (+0.29), GHG emissions (+1.57), and land use (+2.86) will increase. The highest scores in the sustainability indicators are attributed to food safety (4.29 out of 5), economic growth (4.14), land use, and food quality (3.86). On the other hand, income distribution (2.86) and energy dependence (2.43) would still be below the neutral average (3.00).		 Radar plot across the 13 sustainability indicators (1=very bad, 3=neutral, to 5=very good)

Figure 3. Intensification scenario

5.1.1 Improvement of farm and land management

The *fortification of grass* can be conveyed both by changing the grass species or fortifying the grass already adapted to the soil. Changing the grass species adds N and P to the grassland. Another important practice encompasses the intensive grass rotation system. The agrosilvopastoral system is a production system that integrates forest, crop and animal production in a coherent framework of operations. The improvement of animal husbandry with the confinement of the animal is important for managing the cattle more intensively and the manure more efficiently. *Nutrient cycling*, in this case, would benefit from the construction of fences or other types of confinement or from the design of watery points to strategically distribute the excreta (scientific management of slurry). Finally, the *use of support tools* such as DSS is important, for example to avoid nutrient imbalances at the farm or to monitor operations at the different paddocks. Implementing record keeping at the farm and the registration of operations is required, which would be beneficial to all the other chain members and should be rewarded through the price received by the farmer.

5.1.2 Production efficiency

The *animal slaughter age* should be optimised to when the animal is full-grown, given more region-specific research upfront on the species and on age-specific feedlots. The next step is to create awareness among consumers that decreasing the slaughter age of the animal can be beneficial for the environment, via awareness campaigns (Carpentier *et al.*, 2001). Moreover, the rancher has to manage the herd more intensively to realise

its potential, and an increase in capital and labour is necessary to better manage the operations at the farm. Regarding the *feeding technologies*, the primary actions concern the improvement of the rotation of grass, and the use of nitrogen fertiliser and lime. Clustering the animals in age-homogeneous groups at the farm will ease the feeding operations. The literature stresses the importance of the dry season in which extra feed, shade and fresh water should be available (WSPA, 2012).

Genetic improvement involves better selection, cross-breeding, and, most importantly, artificial insemination. Finally, an *action plan for efficiency at the farm* (for recording operations, monitoring and prioritising actions) is of pivotal importance and an improvement in record keeping is required (e.g. using DSS and external expertise).

5.1.3 Tradability improvements

The *animal welfare considerations* encompass the implementation of an action plan for animal welfare in the chain, the use of an agrosilvopastoral system (shade for the animals), and the adaptation of the EU regulations to the Brazilian case (e.g. follow the OIE guidelines). The *requirement and monitoring of an HACCP system* from chain players is of fundamental importance for the tradability of the beef meat and a traceability system should already be in place. Concerning the *payment criteria*, a governmental action to precisely define quality categories and to establish quality control protocols is needed. These quality categories should be set according to the main markets of reference of the production chain. *Electronic identification* is the easiest requirement, to enable tracking and tracing of the material flows in the chain (e.g. tagging the animals and record keeping at the farm).

The *requirement of a monitoring system* is important, especially where the preventive use of antibiotics is not allowed. The government should step in to monitor food safety and establish a chain-wide monitoring system. A *documentation system* is needed throughout the supply chain (promoted and stimulated by government), facilitated by the use of user-friendly systems.

Finally, *compliance with the carcass certification schemes* (farmers and slaughters) and GLOBAL GAP is of pivotal importance (WSPA, 2012).

5.2 'Sophistication' of the pork chains

This sustainability scenario brings about a significant number of sustainable practices, grouped in three categories of improvement options: *production chain improvements, governance improvements,* and *local for local and local for international improvements*.

The following three sections will detail these three categories of sustainable practices to describe the concrete actions to make this sustainability scenario feasible in the Brazilian case.

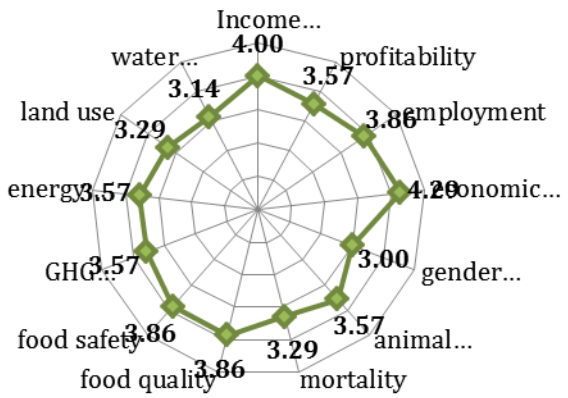
Summarised illustration of: *Sophistication*		
Categories of sustainable interventions	**Sustainable practices involved**	**Sustainability assessment: From the current level of sustainability of pork chains (upper plot) to the sustainability level from implementation of the scenario (lower plot)**
Production chain improvements	Switch from a commodity system to a more diversified pork sector Operational excellence and scale increase Creation of new niches Better outdoor access Genetic improvement Different nutrition Nutrient recycling Improve manure management	
Governance improvements	Initiatives to increase the coordination in the chain Invest in meat quality and traceability Establish claims and standards Campaigns to inform people and increase pork consumption	
Local for local and local for international improvements	Local slaughtering Local meat processing Local raw material purchases Local feed stuff supply Ensure short commercial channels	
According to the radar plot on the bottom, the implementation of this scenario would bring about an improvement in income distribution (+2.00), profitability, GHG emissions (+1.57), animal welfare, energy dependence (+0.57), food safety (+0.86), and land use (+1.29). The highest scores have been attributed to economic growth (4.29), and income distribution (4.00). The other sustainability indicators have been scored above the neutral average, except gender equality (3.00).		Radar plot across the 13 sustainability indicators (1=very bad, 3=neutral, to 5=very good)

Figure 4. Sophistication scenario

5.2.1 Production chain improvements

Several new approaches have to be embraced in the production chain, to make the pork sector more sophisticated. The *switch from a commodity system to a more diversified pork sector* requires market research at the internal and international level. The drivers of diversification should be quality and animal welfare, and the retailer should be the architect of these quality category definitions, rewarding those suppliers able to provide it. Therefore, the use of alternative or new production systems that are more sustainability oriented, the implementation in the chain of traceability systems, and the compliance with quality assurance schemes (e.g. GLOBALGAP) are necessary. *Operational excellence and scale increases* are feasible; prior investigation of the possible environmental diseconomies brought by more coordination in the chain reduces transaction costs and risk. The standardisation of the chain processes brought about by the use of a quality assurance scheme and its monitoring are important. The *creation of new niches* is the essence of diversification, starting from the production chain (market research beforehand and certification to back the claim). In general, the diversification is provided by the new properties of the product (e.g. outdoor access with shaded areas, innovative husbandry, genetic improvement, feed from responsible soy initiatives) or by the diversification of the market outlet. *Nutrient recycling* is improved by advanced manure management supported by technologies such as biodigesters, for the processing of manure into usable end- and by-products.

5.2.2 Governance improvements

The independent producers (involving 10% of the meat whose production is not contracted) should offer room for *new systems of coordination* and create niche markets with more added value products. Better coordination is possible prior to the establishment of inter-branch organisations, and the establishment of a good *information system for traceability* (quality enabler). An identification system must be established, as well as governmental or chain *initiatives to support the quality claims* of the diversified chains (e.g. as with GLOBALGAP). These chains, as mentioned above, need to *comply with sustainability standards*, to back their claims (the market opportunities have to be researched upfront).

5.2.3 Local for local

Local slaughtering and local meat processing should be supported by optimisation of slaughter capacity utilisation and optimal sourcing strategies. As far as the *local raw material* purchases are concerned, for example integrating crop and animal production, economic compatibility has to be verified. *Local feedstuff supply* can be obtained by means of contracts, vertical integration (to enhance chain coordination), and an agronomic analysis on the main cost drivers of production. Finally, *ensuring short commercial channels* is an opportunity when local scale potential is first proven and then promoted.

5.3 Other scenarios

Appendix 2 includes a schematic illustration with the assessment of each of the other four scenarios described here: *local production and sustainable operations* (beef), *integrated land use* (beef), *integration of animal and crop production* (pork), and *balanced sustainability* (pork).

6. Theoretical and managerial implications

6.1 Theoretical implications

The issue of designing a methodology that produces sustainable production and distribution scenarios is investigated in this paper. This study aims to fill a knowledge gap reflected by an in-depth literature research about sustainability scenarios in the Brazilian beef and pork chains derived from a qualitative bottom-up procedure. The results show that, as expected, the scenarios to improve the future state of sustainability of the two chains are profoundly diverse, since they respond to different sustainability issues. Besides the numerous chain-specific practices, a consistent number of sustainable practices are common between the beef and pork chain, as well as recommendable for other food chains (see table below).

Table 4.
Common practices

Common sustainable practices*		
• Improvement of nutrient recycling	• Implementation of a monitoring system for food safety in the chain	• Increase of the sustainability-oriented regulation
• Use of decision support systems	• Improvement of sustainable transport	• Use of feed-print models, local slaughtering and local feed stuff supply
• Genetic improvement of animals and feed	• More coordination in the chain and governmental initiatives that level the benefits of the chain partners (especially improvement of the farm level)	• Establishment of a worldwide accepted sustainability standard for food chains
• Animal welfare considerations		• Record keeping at the farm
• HACCP system applied in the chain		
• Electronic identification of the animals		

**No specific order*

These sustainable practices are scattered within the chosen categories of sustainability interventions at different levels of the chain.

The findings appear to be in line with the dominant literature reviewed that has promoted the importance of chain collaboration, information sharing in the chain and governmental involvement. Indeed, the uniqueness of these results lies in: 1) the '*three-phase methodology*' that provides sustainable production and distribution scenarios for beef and pork supply chains in Brazil, and 2) the *'six scenarios'*, which provide guidelines as groups of sustainable practices to facilitate the planning of sustainable interventions in these Brazilian chains.

The *Sustainability scenario framework* presented below synthesises the findings obtained from the application of the three-phase methodology (sustainability indicators, scenarios, and categories of sustainability interventions).

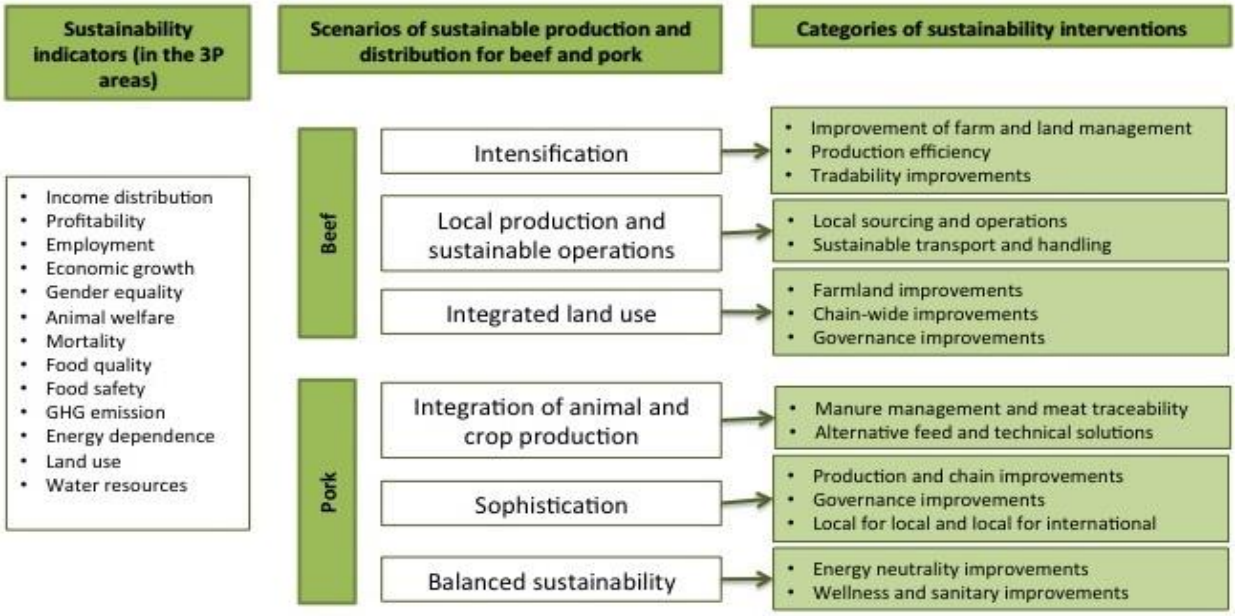


Figure 5. *Sustainability scenario framework* shows: the sustainability indicators, the six scenarios, and the categories of sustainability interventions.

The Sustainability scenario framework displays the logic that has been followed in order to fulfil the objective of this research, and it makes clear how the results have been structured.

Further research should establish to what extent the replicability in other meat chains is possible. Moreover, the three research phases need to be evaluated according to cases other than beef and pork in Brazil.

6.2 Managerial implications

This study shows a correspondence between literature and experts' opinion on the sustainability scenarios that are necessary and feasible, in order to improve sustainability in the Brazilian beef and pork supply chains.

Specifically, the **sustainability indicators** selected from the literature on sustainable development are illustrated in Table 3, and belong to the 3P areas of sustainability, namely: economic, social and environmental.

A number of sustainability issues are common to both the beef and pork supply chains. Differences relate to animal welfare, which mostly involve insufficient feed during the dry seasons for beef, while as far as the pork chain is concerned, welfare relates mostly to insufficient outdoor access at the housing level. GHG emissions are also a major concern. For beef the main sustainability issue is related to enteric methane emissions, while for pork emissions occurring during transport, the production of feed, and mostly through the slurry into the soil and groundwater (leaching) is relevant.

The importance of these findings is paramount not only for supporting the practitioners. In fact, the methodology used to generate scenarios can be extended to other food chains than beef and pork, in the Brazilian area, or to chains in geographical locations other than Brazil.

6.3 Limitations and directions for further research

One limitation is that the selection of thirteen sustainability indicators might not cover all the sustainability issues that food supply chains face in Brazil, as elsewhere. However, it can be argued that the indicators chosen are highly relevant in the panorama of the literature reviewed.

The second limitation regards the four criteria used to screen out the draft scenarios and come to the three scenarios of sustainable production and distribution for beef and the three for pork. These are designed to provide a logical and content-wise selection of scenarios. Although the number of experts involved will always have its limitations, the methodology lends itself very well to future empirical applications in other food chains. Future research directions are to implement the multi-phase methodology to pilot chains other than beef and pork.

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Appendix 1 – the six sustainability scenarios

The upper part of the table describes the sustainability scenarios for beef, while the lower part of the table looks at the scenarios for pork. The components of the table are: the scenarios of sustainability for the beef (three) and pork (three) chains, the sustainability indicators addressed by the scenario, and the sustainable practices involved in the scenario.

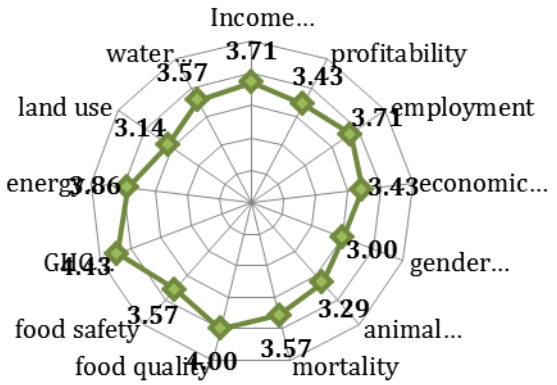
Table 5.
Scenarios, indicators and practices

	Scenarios of sustainable production and distribution	Sustainability indicators addressed	Sustainable practices
Beef supply chains	**Intensification** • Intensification of the beef production systems • Apply carcass certification schemes	• GHG emissions • Land use • Energy dependence • Income distribution • Profitability • Food safety • Food quality	Fortification of the grass. Nutrient recycling. Local feedstuff supply. Give importance to welfare considerations (i.e. more shade for beef). Monitoring systems especially where preventive antibiotics are not allowed. Use grain (bought from another area) instead of grazing grass, and extra feed in dry seasons. Improve the feeding technologies (better feed, slaughter the animal when younger, less emissions). Improve grass and land management (farm management techniques). Optimisation of animal slaughter age and valorise the products when it comes from young beef. Governance system could stimulate the use of DSS to help farmers make operations more efficient. HACCP system. Genetic improvement of animals and feed. Make the farms more efficient. Efficiency action plan at the farm. Mix of organic and intensive beef production system. Use concentrated feed. Pay according to quality categories. Use tags to check sanitary status of herd, transportation following the limits (no. heads) set by the law. Documentation system with farmers registering operations (document practices).
	Local production and sustainable operations • Reduce transport (shorter routes) • Renew infrastructure	• GHG emissions • Energy dependence Animal welfare • Employment • • Economic growth • Food quality •	Improve sustainable transport (river, low impacting vehicles) and support sustainable beef production systems. Expand the transportation network, but with the use of sustainable modes. Local slaughtering. Local meat processing. Local feedstuff supply. Improve legislation on live animal transport and slaughtering welfare, support investments in modern vehicles. Improve education on relationship between animal welfare and meat quality. Pay price according to meat quality.
	Integrated land use • Integration of crop and animal production • Agrosilvopastoral system • Fostering local product marketing • Mix and intensive production systems • Avoid trade with countries with less strict rules	• GHG emissions • Land use • Employment • Animal welfare • Income distribution • Food quality • Food safety • Profitability • Economic growth	Nutrient recycling. Perform toxicological integrative studies on agro-systems. Ensure optimal conditions for animal transport, shortening distance of animal transportation. Subsidise local production to be more self-sufficient and place the locally produced goods on the market. Improve research on mixed beef production systems (alternative to extensive). Increase the research on organic and other sustainable beef production technical development (e.g. agrosilvopastoral systems). Use of more balanced production systems (soy, corn and Brachiaria) to avoid cattle weight loss in the dry period. Improve grazing techniques (more intelligent grazing techniques). Increase differentiation in quality by introducing more labour-intensive and quality-enhancing production processes (e.g. certified beef). Invest in local roads and agroindustry (e.g. mills, pasteurisers). Give support, subsidies to farmers to increase their profitability, so that they can invest. Fair trade initiatives and information campaigns in China and India to inform consumers about sustainability in beef chains (increase public opinion about sustainability). Pressure on political parties to establish more sustainability-oriented regulations and enhance the entry barriers for supplies. Monitoring systems especially where preventive antibiotics are not allowed.

Pork supply chains	**Integration of animal and crop production** • Integration of animal and crop production • Use of feed sources that do not compete with human consumption • Re-use of manure to make organic fertiliser • Use feed suitable for human consumption monitored with feed-print models	• GHG emissions • Energy dependence • Water resources • Land use • Animal welfare • Income distribution • Employment • Profitability • Economic growth •	Government should be responsible for the construction of infrastructure (a lot of dirt roads), and build insemination centres. Tailor feed regimes of extensive farm system to a more intensive regime. Use concentrated feed. Establish a worldwide quality and sustainability standard (focus on food security and food safety). Regulation level has to be higher, to comply with international levels of quality. Nutrient recycling between agricultural sectors Invest in biofuel production from the process of manure into energy and the by-product can still become a fertiliser. Use fertilisers made from manure. Make sure that the animal feed is not in competition with food intended for human use (use by-products). Invest in meat quality and traceability. Use DSS and models to optimise the nutritional value of the feed ingredient on cost price and animal performance (using % of by-products in the formula). Mix manure with straw to create a fertiliser and sell it branded. Use a feed-print model (optimise each ingredient on CO_2 equivalents of the feed production, maintaining the expected animal performance at high level).
	Sophistication • Diversified chains • Local meat processing and local raw material purchasing • Enhance Brazilian internal market	• Energy dependence • Income distribution • Animal welfare • Food quality • Profitability • Economic growth •	Switch from commodity system to a more diversified pork sector (e.g. the KDR chains). Local slaughtering. Local meat processing. Local raw material purchases. Local feedstuff supply (% of money that is produced locally and retained internally should be higher). Nutrient recycling between agricultural sectors. Improve manure management (make energy out of manure) and methane use. Put pressure on these supply chains to establish sustainable claims and standards. Campaigns to inform people (challenge prejudices about pork meat as fatty and unhealthy). Better outdoor access (housing). Genetic improvement. Different nutrition (more responsible), recognisable with claims on a label. The independent producers should offer room for new systems of coordination and create niche markets. Invest in meat quality and traceability. Ensure short commercial channels. Operational excellence and scale increase. Create new niches.
	Balanced sustainability • Animal welfare in global agenda and minimise microbe resistance in humans from use of antibiotics and heavy metals during animal production • More sustainability standards to be applied in the supply chain	• GHG emission • Energy dependence • Animal welfare • Food safety • Profitability	Biogas investment to make energy for the feed mills (cost-benefit analysis on self-sufficiency in energy use). Establish new sustainability standards to be applied in Brazil. Make the system more animal-friendly, especially at the housing level. Invest in monitoring system in SC to manage residues and antibiotic resistant bacteria. Campaigns to inform people (challenge prejudices about pork meat as fatty and unhealthy). Minimise risk of development of microbe resistance of human in the chains (exposure to antibiotic resistant bacteria). Mix manure with straw to create a fertiliser and sell it branded.

Appendix 2 – illustration of the other four scenarios

A2.1 – Local production and sustainable operations

Summarised illustration of: *Local production and sustainable operations*		
Categories of sustainability interventions	**Sustainable practices involved**	**Sustainability assessment: the sustainability level from implementation of the scenario**
Local sourcing and operations	Local slaughtering Local meat processing Local feedstuff supply	
Sustainable transport and handling	Improve the sustainable transport Expand transportation network Improve the legislation on live animal transport Improve the education on relationship between animal welfare and meat quality Pay price according to meat quality.	

Radar plot from the re-elaboration of the 5-point Likert scales across the 13 sustainability indicators (1=very bad, 3=neutral, to 5=very good)

According to the radar plot, the implementation of this scenario would bring about an improvement in income distribution (+1.71), profitability (+1.43), employment (+0.71), animal welfare (+0.29), food quality (+1.00), GHG emissions (+2.43), and land use (+2.14). The highest scores are attributed to GHG emissions (4.43) and energy dependence (3.86). Overall, the scenario brings about improvements in all the sustainability indicators (the lowest are gender equality and land use, however still above 3.00).

Figure 6. local production

A2.2 – Integrated land use

Summarised illustration of: *Integrated land use*

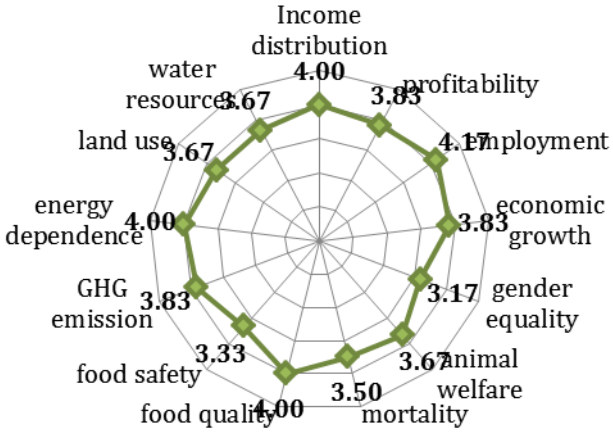
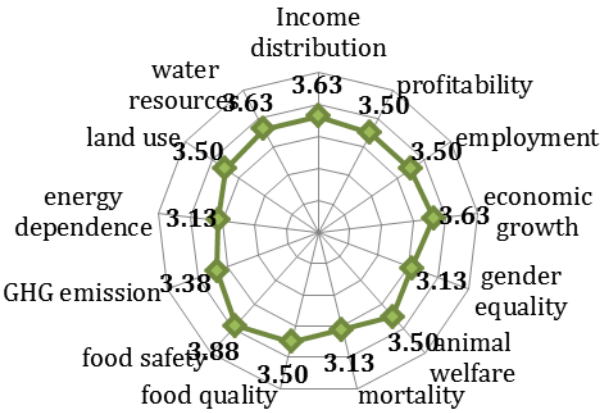
Categories of sustainability interventions	Sustainable practices involved	Sustainability assessment: the sustainability level from implementation of the scenario
Farmland improvements	Nutrient recycling Improve research on mixed beef production systems Increase research on organic and other sustainable production technical developments Use of more balanced production systems Improve grazing techniques Tailor feed regimes to more intensive and use of concentrated feed	
Chain-wide improvements	Increase differentiation in quality by introducing more labour-intensive and quality-enhancing production processes Perform toxicological integrative studies on agrosilvopastoral systems Ensure optimal conditions of animal transport Invest in local roads and agroindustry	
Governance improvements	Give support to farmers to increase profitability Government responsible for infrastructure investments Subsidise local production Monitoring system Fair trade initiatives and awareness campaigns in China and India More sustainability-oriented regulations Establish a worldwide quality and sustainability standard Increase in the regulation level	Radar plot from the re-elaboration of the 5-point Likert scales across the 13 sustainability indicators (1=very bad, 3=neutral, to 5=very good) According to the radar plot, the implementation of this scenario would bring about an improvement in income distribution (+2.00), profitability (+1.43), employment (+1.17), animal welfare (+0.67), food quality (+1.00), GHG emissions (+1.83), and land use (+2.67). The highest scores are attributed to employment (4.17), energy dependence, food quality, and income distribution (4.00). The experts have attributed the lowest scores to gender equality (3.17) and food safety (3.33), even though they are above 3.00.

Figure 7. Integrated land use

A2.3 – Integration of animal and crop production

Summarised illustration of: *Integration of animal and crop production*		
Categories of sustainability interventions	**Sustainable practices involved**	**Sustainability assessment: the sustainability level from implementation of the scenario**
Manure management and meat traceability	Nutrient recycle Invest in a biodigester to process manure into energy and fertiliser Invest in meat quality and traceability	
Alternative feed and technical solutions	Use animal feed not in competition with human consumption Use DSS to optimise the nutritional value of feed ingredients Use of feed-print models	

According to the radar plot, the implementation of this scenario would bring about an improvement in income distribution (+1.63), profitability (+1.50), animal welfare (+0.50), food safety (+0.88), GHG emissions (+1.38), energy dependence (+0.13), and land use (+1.50). The highest score has been attributed to food safety (3.88), while the lowest sustainability scores have been attributed to gender equality, mortality and energy dependence (3.13). All the values are between 3.13 and 3.88, therefore above the neutral average of 3.00.

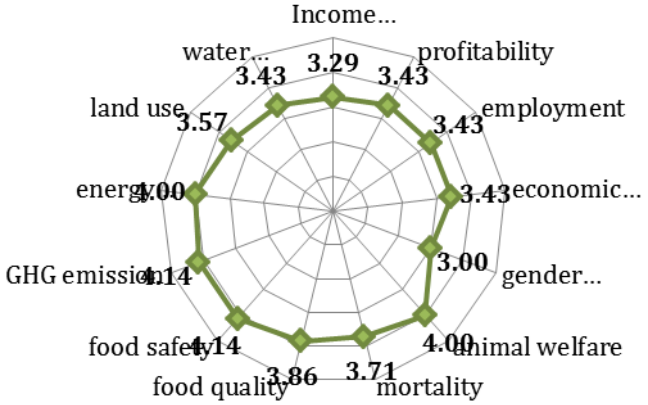


Radar plot from the re-elaboration of the 5-points Likert scales across the 13 sustainability indicators (1=very bad, 3=neutral, to 5=very good)

Figure 8. Integration of animal and crop production

A2.4 – Balanced sustainability

Summarised illustration of: *Balanced sustainability*		
Categories of sustainability interventions	**Sustainable practices involved**	**Sustainability assessment: the sustainability level from implementation of the scenario**
Energy neutrality improvements	Biogas investment to make energy for the feed mills	
Wellness and sanitary improvements	Make SC operations more animal-friendly Investment in a monitoring system for residues management Minimise the risk of development of microbe resistance Establishment of new sustainability standards Campaigns to inform people and increase pork consumption	



Radar plot from the re-elaboration of the 5-point Likert scales across the 13 sustainability indicators (1=very bad, 3=neutral, to 5=very good)

According to the radar plot on the right, the implementation of this scenario would bring about an improvement in income distribution (+1.29), profitability (+1.43), animal welfare, energy dependence (+1.00), food safety (+1.14), GHG emissions (+2.14), and land use (+1.57). The highest scores have been attributed to food safety and GHG emissions (4.14), animal welfare and energy dependence (4.00). All the other sustainability indicators are above the neutral average, apart from gender equality (3.00).

Figure 9. Balanced sustainability