3rd International Conference on Energy and Environment: bringing together Engineering and Economics
Porto, Portugal
29-30 June, 2017

SUSTAINABILITY INDICATORS IN INTEGRATED PRODUCTION CHAINS: A MODEL AND AN APPLICATION

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KEYWORDS
Supply Chains, Sustainability, Performance Measures.

ABSTRACT

In recent decades there has been a growing concern about measuring and evaluating the results of intensive production practices, such as the mode of integration practiced on a large scale by agro-industries. The present study had as one of its finalities the application of a Sustainability Indicators System in the context of pig farms in the Brazilian State of Santa Catarina. These indicators, focused on the level of sustainability maturity, can be used as a way to diagnose and compare the efficiency of the production chain. The research findings indicate that all can be classified as "in search of sustainability or sustainable". Nevertheless, there are differences among the dimensions and between the most ranked farms and the others which must be considered for a better design and application of public policies and company strategies towards the social, economic and environmental sustainability of integrated production chains in this and other industries.

INTRODUCTION

In recent decades there has been a growing concern about the global problems posed by environmental and social movements. In particular, measuring and evaluating the results of intensive production practices, such as the mode of integration practiced on a large scale by agro-industries. In fact, any activity or organization that aims business success, in today's competitive and globalized market scenario, must be structured or restructured to production systems that meet sustainability requirements in terms of social, economic and environmental dimensions (Elkington, 2007).

Brazil is now the fourth largest producer in the world and the fifth largest consumer of pork in the world. The state of Santa Catarina is the fourth largest exporter in the national context. Regarding the type of production, it is usually based on an integrated system, acting in the various production stages, from the very beginning of the process till the distribution to the client (Empresa Pesquisa Agropecuária e Extensão Rural de Santa Catarina EPAGRI, 2017).

Such integration has been a response to the growing demand for food, resulting in important changes in the production system of animals, going from typical family owned independent production units to a complete cycle integration mode, which is currently predominant in the pig production system in the southern region of Brazil, where about 92% of swine establishments are acting under integrated contracts or development programs lead by large agro-industrial companies or cooperatives (Miele, 2006).

This integrated production system made it possible to finance the producers, gave a commercialization scale to the agro-industries, facilitated the transfer of technologies, among other benefits to the pig production chain, thus allowing the development of several regions such as the “Alto Uruguai” in Rio Grande do Sul and Santa Catarina and, more recently, by moving and including other industries of this supply chain namely, grain-producing centers located in the central west of Brazil (Allegreti et al., 2014).

The growing numbers of Brazilian pig farms in the national and international markets, due to increases in production efficiency and competitiveness of the sector, ask to the need for adequate evaluations regarding the analysis of the sustainability of the activity. The increase in pork production in Brazil in recent decades has been due to the increase in the scale, specialization and geographical concentration of primary production. Concomitantly, it was observed an increase in the number of contracts that govern the relations between producers and agribusiness involving, for example, most of the producers in the termination stage (Miele, 2006).

Furthermore, the intensification of swine farming in recent decades has led to changes in the profile of municipalities and pig farms, bringing environmental, social and economic consequences to be better evaluated. Increasingly environmental impacts are being felt as a result of the high polluting potential of pig production due to the waste

generated, as points to be observed in the analysis of the development of the sector, especially in the most representative pig producing regions of the country (Kruger et al., 2015; Allegretti, 2014; Miranda, 2005; De Haan and Blackburn, 1995).

Indeed, there is a need to monitor environmental issues in pig production, regardless of whether it is due to societal pressures or an increase in the demands of inspection bodies. The vision of a sustainable management of these production chains, integrating the activities among all relevant actors (farmers, agribusiness, suppliers, public agents and clients) is fundamental, interacting and participating in the construction of effective conditions for a sustainable swine production chain.

In the literature on sustainability indicators, one of the identified gaps concerns the users of these indicators. In fact, they should be used and taken into consideration by producers but they are essentially a concern for public decision makers and researchers.

The present study had as one of its finalities the application of a Sustainability Indicators System (SIS) for agro-industries following the one proposed by Peruzatto (2009). The developed model has been applied in the context of pig farms in the Brazilian State of Santa Catarina. These indicators, focused on the level of sustainability maturity, can be used as a way to diagnose and compare the efficiency of the swine production chain.

The study is justified by addressing a contemporary problem, which is sustainability in the context of the production and supply chain. The case study is also relevant considering the importance of the agribusiness for the local and national economy. Research of this nature also offers the potential to present empirical findings that aim to contribute significantly to the understanding of such phenomena, mainly on aspects of environmental and social impacts, presenting methods of measuring and evaluating significant polluting agricultural activities, such as the pork supply chain.

A MODEL FOR SUSTAINABILITY MEASUREMENT IN INTEGRATED PRODUCTION CHAINS

The model developed and applied in this research was based on the model developed by Peruzatto (2009) and other models that present variables and dimensions of sustainability (Oliveira, 2002; Miranda, 2005; Pastakia, 2008).

Oliveira (2002) proposed the creation of a Sustainability Indicators Assessment Method (SIAM) that could be applied to any type of organization, regardless of the type of activity or size of the company. This method presents the organization through four dimensions of sustainability, and for each dimension ten indicators are evaluated, which, once weighted, allow the definition of maturity levels for the organization in terms of sustainability. The maturity level of the organization according to the dimensions of sustainability and its indicators, allow the prioritization of corrective or preventive actions in the organization strategy in search of continuous improvement for sustainable development. The SIAM made use of technical standards (ISO 9000 series, ISO 14000, BS 8800, 8000) and the recommendations of Sachs (1992) to define dimensions and indicators.

On the other hand, Gama (2003) aimed to propose a multi-criteria assessment methodology for the selection of alternatives for treatment of swine manure in order to respect socio-economic-environmental conditions in the Federal District. The environmental impacts of the swine economy chain were collected and quantified through SIAM in comparison a multi-criteria method for the decision-making process, the Analytical Hierarchy Process (AHP). The author concluded that the integration of methods is a useful tool for environmental planning and management, integrating the objectives of raising the quality standards of natural resources.

The Rapid Impact Assessment Matrix (RIAM) method was proposed by Pataskia (2008). The author sought to evaluate the significance of the impacts of the different activities and how they are evaluated in comparison with the environmental components. The survey looked at projects in central Finland that had been funded by the European Union and for which sevral aspects related to the sustainability dimensions can be evaluated namely, environmental, social and economic impacts. The results evidenced that the scoreboard presented by SIAM could be used as a generic method for the measurement of social impacts.

Peruzatto (2009) states that the measurement of sustainability must be made under two general criteria: Efficiency and Extent. The evaluation of the results of the Efficiency level (NC1) of each indicator is made by the equation "(NC1 * PC1)" which is the individual weight of value per indicator and by criterion. An acceptance limit of up to 25% of variance is assigned between the Efficiency result and the mean, if above the indicator it is excluded. For the second criterion (C2), the extent of the Indicator is evaluated, measured by the degree of impact evaluated by the specialists in each proposed dimension, that is based on the space limit or of common interest for all.

For isonomy between the criteria, it was considered a limit of up to 25% of variance with the average of the indicator, and if there is no indicator in one of the criteria, a zero value was assigned, eliminating its weight in the influence of the criterion. For example, if any indicator is zero in terms of Efficiency, automatically it will be zero in terms of Extent, because: (N1C * P1C), would be like (0 * (1, 2, 3, 4)).

The evaluation of each indicator is done by the following equation:

$$AI\ n = ((N1C*P1C)+NC2)*PMD \qquad (1)$$

Where:
NC1 – evaluation from the field research
PC1 – average of evaluation made by specialists through a questionnaire in the field research
NC2 – average of evaluation made by specialists for the extent
PMD – average weight of each dimension (AD = $\sum_{n=1}^{n} A\ I\ n$)
AFD – final evaluation of the dimension (DA+DE+DS+DP= A I n)

The objective of the this method is to evaluate the planning, implementation and execution of sustainability, measured through a set of indicators, using data obtained from field research and validated by indicator and by dimension. As a result, each company is evaluated in one of the following three levels (Table 1).

Table 1: Sustainability maturity levels

Level	Final Evaluation
Sustainable	7,60 – 10,00
In Search of Sustainability	5,20 – 07,50
Unsustainable	0,00 – 05,10

Source: Peruzatto (2009).

Gomes et al. (2014) used the model of Peruzatto (20009) and carried out a research on 12 pig farms in the state of Rio Grande do Sul (Brazil) characterized by different waste management systems, with the objective of evaluating their sustainability. As a result, they confirmed the efficiency and comprehensiveness of the application of these indicators.

METHODOLOGY

A questionnaire was used to collect the dat from the field. The research questionnaire consists of 30 questions, which are distributed in four main dimensions: political-spatial (PD), social (S), economic (EcD) and environmental (EnD).
According to Peruzatto (2009), the spatial political dimension aims to foster initiatives to curb the destruction of fragile ecosystems, promote sustainable management in agriculture and forest exploitation, encourage decentralized industrialization with new generation technologies and help conservation of biodiversity.
With regard to the environmental dimension, this search captures the various ways to promote a sustainable ecology, in order to optimize the resources capacity of the planet, through creativity and use of appropriate technologies; Enjoy the environment in a conscious way, and create more effective means for its protection.
The objective of the economic dimension is to identify if the allocation and management of resources are efficient and if there is a continuous flow of public and private investments.
Concerning the social dimension, the assumptions sought to capture aspects related to the local society where companies operate, exposing the need for paradigm changes, aiming at generating opportunities, income distribution and improving of the quality of life of the communities.
Table 2 presents the structure of the questionnaire based on the four dimensions explained above.

Table 2: Structure of the method

Sustainability dimensions	Number of Indicators	Weight of the dimension	Average weigth of each indicator
Political-Spatial (PD)	5	0,2	0,040
Social (SD)	6	0,1	0,017
Economic (EcD)	7	0,3	0,043
Environmental (EnD)	12	0,4	0,033
Total	30	1	

Source: Gomes et al. (2014).

The environmental dimension is represented with 12 indicators and weighing 40%; Economic: with 7 indicators and 30% of weight; Political: with 5 indicators and 20% of weight; Social: with 6 indicators and 10% of weight. For each indicator, four possible responses were considered, with a score between 0 and 3. A score of 3 means that the indicator exists and is widely used in the day-to-day management of the farm, while zero means that there is no used of such indicator.

ANALYSIS OF FINDINGS

The research was carried out through visits to 8 properties in the western region of Santa Catarina and 6 other properties were researched with the help of Google tools, using e-mails provided by the Catarinense Association of Porcine Breeders. In this way the sample is characterized as non-probalilistic. Data was tabulated using excel software namely, the computation of Efficiency and Extent indicators, based on the responses collected.

The data was obtained from employees or owners of farms producing pigs from western Santa Catarina. Farms have different sizes and types of production. Final responses totaled 14 farms. The period of data collection comprised between July 1 and August 15, 2016.

The collected data initially sought to characterize the studied farms regarding the type of production, time of activity, capacity of housing of animals in the farm, and production system, and later to meet the objective of the research, we sought to investigate the direct effect of the use of sustainability indicators on the studied companies.

The average time of experience in this type of production system of the interviewees was 8 years and a half, with 14% of the pig farmers being relatively new in this activity with only 1 year of experience. Forty-three percent of the respondents had between 10 and 20 years of age in this industry, and another 43% up to 5 years of years, which indicates that pig production is in full growth in the region, since 57% of the interviewed producers have between 1 and 5 years of experience in this industry.

In the pork industry, the supply chain is characterized by a well defined set of activities or companies. The supply chain includes producers, abattoirs and meat processors, transporters, packers, wholesalers, retailers, and export/import distributors. A good supply chain management in agribusiness industries, as it is the case of the pork industry, can improve product quality, efficiency and profitability. According to Miele (2006) farm production and capacity is conditioned to the amount of available land that the property has to treat the waste produced, in an ecologically correct manner.

The aggregated results of the application of the methodoly explained before are presented in Table 3, by dimension and globally.

Table 3: Descriptive statistics of the sustainability measurement model

	Globally	SD	EcD	EnD	PD
Maximum	7.66	0.75	2.51	3.55	1.68
Minimum	5.47	0.30	1.06	2.44	1.08
Average	6.600	0.52	1.78	2.91	1.38
Standard Deviation	0.48817	0.12562	0.26857	0.23500	0.10669

Source: Data from the research.

In this research, companies were distinguished as production units, termination units or full cycle. Regarding the type of farm, it can be noticed that the most experienced producers are those of pig production (P) and full cycle (FC) units. On the other hand, the termination units (T) are characterized by showing producers with less experience, demonstrating that the productive chain has conditions to expand the scale of production, since the termination units represent the majority of the producing units offering capacity for the upstream value chain.

With regard to the production system, all the producers work under the integration scheme, the focal company controls all the value chain being responsible for the logistics and the coordination of operations, technical assistance to producers and transportation. The producer, has the responsibility of supplying all the physical structure and the correct disposal of the wastes occasioned by the pig production, including the labor, which can be outsourced (Talamini et al., 2005).

Accordingly, the results were be also analyzed by farm and comparing production, termination and full cycle units. The results by dimension and globally (i.e. in terms of Efficiency and the Extent) are presented in Table 4.

Table 4: Results by farm

Farms	Age	PD	EnD	EcD	SD	Globally	Classification
P 1	5	1,388	3,0558	1,5050	0,6358	6,5846	In Search of Sustainability
P 2	5	1,460	2,5080	1,8447	0,7429	6,5556	In Search of Sustainability
P 3	10	1,404	3,5541	1,9479	0,7531	7,6591	Sustainable
P 4	20	1,516	2,9436	2,1586	0,3383	6,9565	In Search of Sustainability
P 5	1	1,416	2,9436	1,8275	0,4930	6,6801	In Search of Sustainability
P 6	20	1,516	3,0096	1,8275	0,5457	6,8988	In Search of Sustainability
T 1	10	1,680	2,6994	2,5112	0,4947	7,3853	In Search of Sustainability

T 2	10	1,192	2,6796	1,3889	0,3060	5,5665	In Search of Sustainability
T 3	5	1,368	3,2670	1,9479	0,4641	7,0470	In Search of Sustainability
T 4	5	1,292	3,3000	1,8447	0,6120	7,0487	In Search of Sustainability
T 5	5	1,08	2,4420	1,4878	0,4675	5,4773	In Search of Sustainability
T 6	1	1,416	2,7654	1,6125	0,4199	6,2138	In Search of Sustainability
FC 1	5	1,316	2,7720	2,0554	0,3094	6,4528	In Search of Sustainability
FC 2	20	1,292	2,9172	1,0621	0,7191	5,9904	In Search of Sustainability

Source: Data from the research.

Regarding the average, it can be observed that 57% of the farms are above average in the envonmental dimension, showing that they are efficient and are committed to this dimension. With 64.2% of the farms presenting above-average rates, it is celar that economic aspects are also relevant for these companies. On the other hand, only 43% of the farms showed above-average indicators in the social dimension showing lower committement to these aspects of the sutainability matrix.

Results pointed out that production unit 3 was the most efficient in the overall result, reaching an index of 7.65 and being considered as "sustainable". Although this farm has not obtained the highest marks in all the dimensions surveyed. Indeed, in the political and social dimensions there is still room for improvement; since this level varies between 7.5 to 10. These results highlight that it is necessary to focus on actions that allow greater efficiency in all dimensions, always aiming to achieve high levels of sustainability.

In general, although not reaching 7.5 of the final average, which is the minimum to be considered “Sustainable”, 3 other farms exceeded a result od 7 in the global indicator all of them terminator units (T1, T3 and T4)

Comparing the three types of farms (P, T, FC), the units classified as producers of pigs, had better overall performance to terminators and the later better results as full cycle units.

It can be also observed that the farms with the lower results are associated to with both little experience in the activity (1 and 5 years) but also with a great experience in the industry (20 years). From these results, it is possible to infer that the experience of the owners in the activity is not evidenced as a determining factor of the sustainable dimensions for the farm.

Nevertheless, there are differences among the dimensions and between the most ranked farms and the others which deserve a better attention. Figure 1 shows the global result and by dimension for each farm.

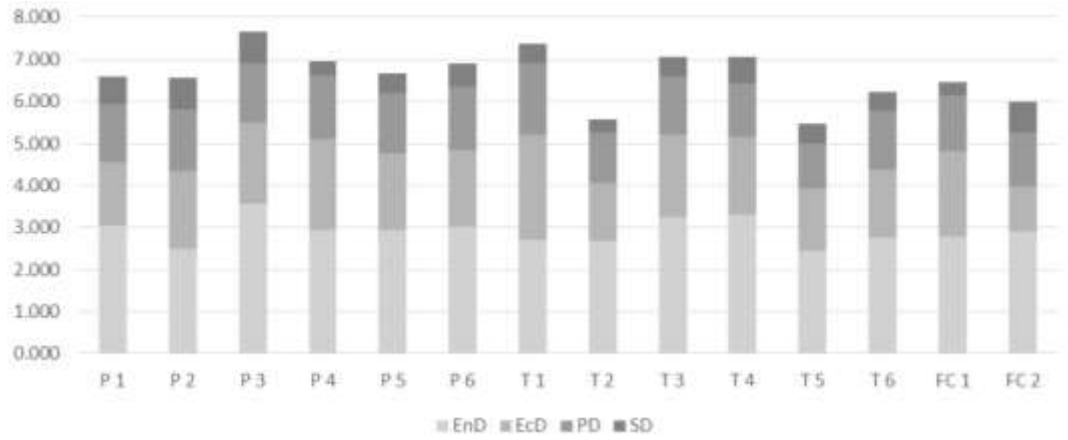

Figure 1: Sustainability indicators by farm

The research findings indicate that all farms in the sample ranged from 5.56 to 7.65 ("in search of sustainability"). These results are consistent with the research of Gomes et al. (2014), who applied a similar model to farms in the Brazilian state of Rio Grande do Sul (they obtained results between 5.5 and 6.8 and classified all studied farms as pursuiting sustainability. Nevertheless, it is noticed that there is great variability of the levels of sustainability of each farm, although almost of them are classified as "in search of sustainability. The greater differences between the better farms and those with lower results were found in economic dimension followed by the environmental dimenson. On the other hand, all the 14 farms present very (low and) similar results for the social dimension.

The search for sustainable development is a constant challenge, which requires the maintenance of the goals and attitudes of the manager and of the employees as a routine activity, it is perceived that in order to achieve the best result in each dimension, it is needed a great engagement of the organization.

The evidence of patterns and trends is important to support a better design and application of public policies and company strategies towards the social, economic and environmental sustainability of integrated production chains in this and other industries.

CONCLUSIONS

The results of this reseach allowed to infer about the level of sustainability of pig farms in the State of Santa Catarina, Brazil, a very important producer and exporter. Indeed, the Catarinense State has the title of largest producer and exporter of pork in Brazil and the fourth largest exporter in the world.

The model presented in this paper, focused on the level of sustainability maturity, can be used as a way to diagnose and compare the effectiveness and efficiency of companies and production chains in this domain. In this case, the research findings indicate that all farms can be classified as "in search of sustainability or sustainable" but just one reached the higher level of sustainability.

The understanding of the different dimensions that contribute to sustainable organizations is important to recognize what must be improved in the short and long term, always in the direction of reaching the highest level of sustainability desired by companies and society. As suggestions for future research, a more large number of farms could be surveyed and the model can be applied in other regions and industries.

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