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Procedia - Social and Behavioral Sciences 223 (2016) 726 – 732

Procedia
Social and Behavioral Sciences

2nd International Symposium "NEW METROPOLITAN PERSPECTIVES" - Strategic planning, spatial planning, economic programs and decision support tools, through the implementation of Horizon/Europe2020. ISTH2020, Reggio Calabria (Italy), 18-20 May 2016

Ranking farms using quantitative indicators of sustainability: the 4Agro method

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Abstract

The paper presents 4Agro, a new model for the assessment of environmental, social and economic sustainability of farms. The framework is based on a set of 42 indicators. The process has involved the following steps: identification of the most relevant variables that characterizes sustainability performances of farms, choice of the appropriate indicators, assignment of their range scores, data collection, calculation of the score for each farm and their visualization by graphic representation. The case study was represented by fifty farms from the South Milan Agricultural Park (Northern Italy). The method allows a comparison among farms or homogeneous groups of them, showing the sensitivity to their characteristics and farmers' choices.The research shows the framework of 4Agro and discusses some relevant points related to the selection and weighting of indicators.

Peer-review under responsibility of the organizing committee of ISTH2020

*Keywords:*Sustainability assessment; Indicators, Environment, Society, Economy.

1. Introduction

Sustainability is a holistic notion based on theeconomic, ecological and social pillars that need to be simultaneously considered to realize more sustainable human activities (Goodland, 1995; Gómez-Limón & Sanchez-Fernandez, 2010).From the methodological point of view, the development of sustainability assessment tools of agriculture is a key issue for researcher that aims at providing decision-making frameworks for both farmers and

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Peer-review under responsibility of the organizing committee of ISTH2020
doi:10.1016/j.sbspro.2016.05.249

policy-makers (Hansen, 1996; Demartini et al., 2015).Nevertheless, concrete attempts of its application as an operational tool to improve agricultural systems are difficult to identify (Hansen, 1996) because putting this theoretical concept into practice involves relevant problemsrelated to the case study, the data requirement and the objective of the research (Meul et al., 2008; Gómez-Limón & Sanchez-Fernandez, 2010).To face these issues, at the farm scale,researchers often use indicators, tools that quantify information through simplification (Singh et al., 2009) and offer an easy communication (Bélanger et al., 2012) useful at the multiple level (Girardin et al., 2000).

The aim of this paper is to present 4Agro, a new method for the evaluation of environmental, social and economic sustainability that uses 42 quantitative indicators. The framework is able to provide easy-to-read results for farmersto assess the effects of managerial changes and for researchers and policy-makers that need to identify agricultural sustainable practices and the farm's characteristics that mostly influence sustainability (Häni et al., 2003; Van Cauwenbergh et al., 2007).

The remainder of the text is organized into four sections.Section 2 presents a literature review onthe main sustainability themes at the farm scale.Section 3 shows the framework, its indicators and the specific case study used in the paper.Section 3 presents the results and their discussion. Finally, a concluding paragraph offers a summary of the research and some reflections on its potentialities and limitations.

2. Literature review

The literature offers a heterogeneous range of sustainability approachesat the farm scale (Hansen, 1996).Nevertheless, many authors have focused their studies on a singlepillarof sustainability while who tried to provide an integrated approachgave them a different relevance (Singh et al., 2009).Consequently, there is an imbalance regarding their weight in the studies on sustainability.

The environmental sustainability is certainly the more studied, Nevertheless, because of a clear difficulty in its conceptualization, many scientists tried to pay more attention to its operational concretization, starting from the definition of its objectives (Gómez-Limón & Sanchez-Fernandez, 2010); in particular the water and soil quality, the maintenance of biodiversity and the issues related to the climate change (Girardin et al., 2000). The achievement of these objectives is more relevant in the intensive agriculture where the economic component has a primary role (Van der Werf & Petit, 2002) and the "ecological disservices" are considerable. Because of that, the local and European institutionsoften provides numerous regulationsandtheir efficiency and effectivenessneed to be verifiedthrough a scientific evaluation of their ability to enhance sustainability (Girardin et al., 2000).

On the contrary, the evaluation of the economic and, especially, social sustainability suffer from a lack of accepted and well-grounded frameworks (Von Wiren-Lehr, 2001).

Contemporary society recognizes agriculture as having an important responsibility in safeguarding the region, its culture and traditions (Gaviglio et al., 2014). Nevertheless, the measurement of social sustainability is less studied and the literature mainly proposes toolsbased on qualitative assessments (see Häni et al., 2003; Van Cauwenbergh et al., 2007; Meul et al., 2008; Vilain et al., 2008).On the consequence, finding a match between the social sustainability objectives (in particular the working condition, the quality of products and the region, the cultural and human development of the rural community) and their corresponding indicators is a challenging taskbecause the perception of social issues is heterogeneous in different territorial contexts (Littig & Griessier, 2005).

Economic sustainability is what contributes to make a farming system perennial (Lien et al., 2007). This involves the capacity of a farm to survive various risks and shocks. In many studies, the economic sustainability is often confined to assessment of its economic viability. Nevertheless, it seems essential to consider the global economic health and profitability of farms that includes its efficiency, transferability, diversification and multifunctionality (Zahm et al., 2008). Moreover, this notion strengthens the role of agriculture in providing environmental services and, at the same time, to offer income diversification opportunities to farmers (Costanza et al., 1997).

3. Material and Methods

3.1. The framework

4Agro aims at the assessment of sustainability of farmsthrough the useof 42 quantitative indicators. Table 1 summarizes the indicatorsand the relative component (indicator's categories) of each pillar.The conceptual framework is derived from a subjective evaluation since the lack of a shared model for the sustainability assessment at the farm scale has allowed to an arbitrary choice of tools (in this case the indicators) (Van Cauwenbergh et al., 2007). In this sense, the key point was the proper balance between the data availability and the significance of the information for specific production systems and geographical context (Meul et al., 2008). In this study, the selectionof indicatorswas carried out through their collection from currently available methods[1]. Among these, the choice was based on a combination of the best characteristics of simplicity, data requirements andsignificance for the case study (see the following paragraph).

Table 1. Indicators (numbered from 1 to 42) and components (main labels in bold).

	Environmental pillar		Social pillar		Economic pillar
Code	Denomination (max score)	Code	Denomination (max score)	Code	Denomination (max score)
ENV_1	*Diversity (50)*	*SOC_1*	*Products the territory (50)*	*ECO_1*	*Economic viability (50)*
1	Annual crops diversity (14)	19	Quality of the products (20)	34	Value of production (30)
2	Tree crops diversity (14)	20	Rural buildings (12)	35	Value added (20)
3	Animal diversity (14)	21	Landscape and territory (18)		
4	Safeguard of genetic diversity (8)				
ENV_2	*Space management (50)*	*SOC_2*	*SFSC, related activities (50)*	*ECO_2*	*Transmissibility (50)*
5	Crop rotation (14)	22	Short food supply chain (30)	36	Farm ability to generate income (25)
6	Plots management (6)	23	Related activities (20)		
7	Ecological buffer zones (20)			37	Income per family worker (25)
8	Environment, landscape (4)				
9	Stocking rate (6)				
ENV_3	*Agricultural practices (50)*	*SOC_3*	*Work (50)*	*ECO_3*	*Independence (50)*
10	Fertilization (20)	24	Work (25)	38	CAP Independence (25)
11	Pesticides (20)	25	Sustainability of the employment (15)	39	Autonomy (25)
12	Veterinary treatments (3)				
13	Livestock effluents (7)	26	Training (10)		
ENV_4	*Natural resources (50)*	*SOC_4*	*Ethics, human development (50)*	*ECO_4*	*Diversification (50)*
14	Soil management (20)	27	Livestock management (25)	40	Diversification of the production (30)
15	Water management (20)	28	Associations and social implications (15)		
16	Organic matter (10)			41	Farm business diversification (20)
		29	Cooperation (10)		
ENV_5	*Energy management (50)*	*SOC_5*	*Society, culture, ecology (50)*	*ECO_5*	*Multifunctionality (50)*
17	Energy dependence (25)	30	Waste management (15)	42	Multifunctionality (50)
18	Renewable energy (25)	31	Accessibility to farm spaces (10)		
		32	Sustainable use of materials (15)		
		33	Education (10)		

The method is characterized by an aggregative structure (Fig. 1) aimed at reducing data from farm characteristics to sub-indicators, indicators, components and, lastly, a unique value of each pillar. By this way, the farm characteristics are converted into dimensionless values that represent an easy-to-read score of the raw data according to the desirability of the measured performance.As shown in Figure 1, the process is divided into 4 basic phases:

- Phase 1: collection and analysis ($F_{(x)}$ and $G_{(x)}$) of the farms' characteristics, in order to obtain a raw data set;

[1] See Häni et al., 2003; Van Cauwenbergh et al., 2007; Vilain et al., 2008; Meul et al., 2008; Reig-Martinez et al., 2011;Bélanger et al., 2012; Thiollet-Scholtus et al., 2015; Paracchini et al., 2015.

- Phase 2: the elaboration of 75 sub-indicators leads to integer and dimensionless values that range from negative to positive values, according to their maximum scores;
- Phase 3: calculation of the indicators obtained through the sum of two or more sub-indicators. A minimum [0] and a maximum score [variable depending on the relevance attributed to the indicator] is applied;
- Phase 4: the sum of two or more indicators provides the value of each component. A minimum [0] and a maximum [50] score is applied. In turn, the sum of the components leads to the overall value of eachpillar of sustainability, which can range from 0 to 250.

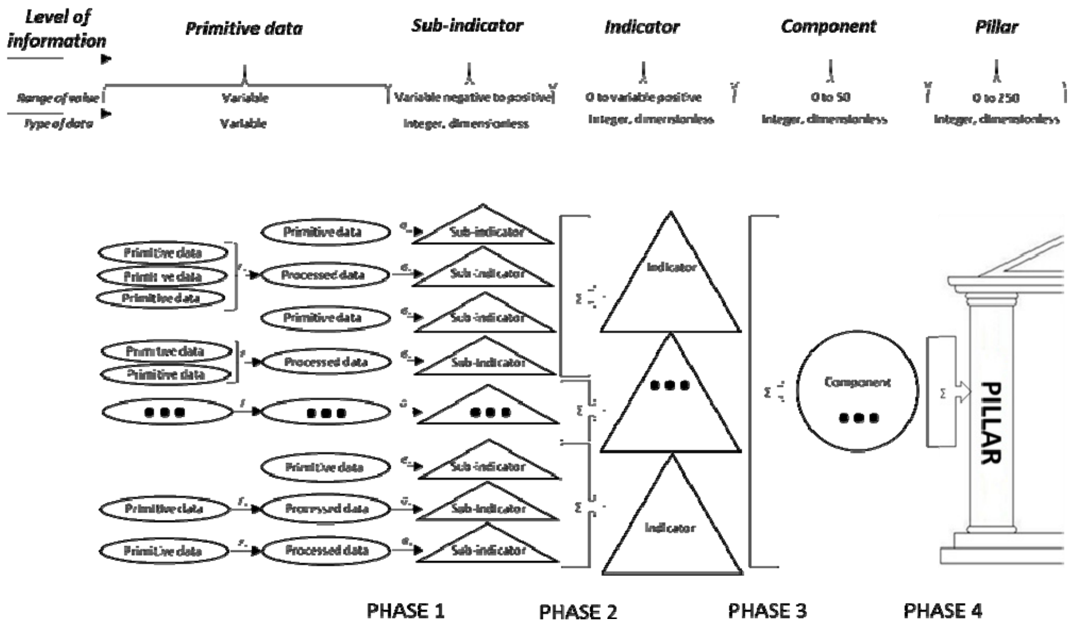

Fig. 1. The 4Agro framework.

Like theselection process of indicators, their weighting procedure has derived from a subjective evaluation (Von Wirén_Lehr, 2001). While this process involves the typical risks connected to subjective norms but it seems difficult to avoid since the importance given to the various indicators strictly depends on the objectives of the sustainability evaluation and the geographical, technical, economic and political context. Thus, sustainability indicators cannot be considered equally relevant with reference to sustainability assessment (Vilain et al., 2008; Zahm et al., 2008).

3.2. Case study

The survey was carried out on a set offarms belonging to the South Milan Agricultural Park (Parco Agricolo Sud Milano, PASM), a intensive-production peri-urban park (35,000 hectares) embracing the southern, eastern and western areas of the city of Milan (northern Italy).Fifty farms with different production systems and economic dimension were selected and analyzed during the 2012-2014 period. The sampling process was carried out using data provided by the SIARL database (Sistema Informativo Agricolo Regione Lombardia). Data of each farm were collected using: (i) interviews; (ii) SIARL; (iii) PASM'sofficial documents.

4. Results and discussion

Indicator, component and pillar's scores allow various approaches of data reduction in relation to the sample features and the objective of the research.The model is able to describe the farm performances through the so-called

Farms ranking approaches. The Fig. 2 shows four examples of data elaboration, graphically represented by radar diagrams (Von Wirén-Lehr, 2001). Farms have been classified considering some of their characteristics and they have been compared among homogeneous groups.

In Fig. 2a, theaverage scores of 41 conventional farms and 9 organic farmsof the sample are compared. Compatibly to what found by Paracchini et al. (2015), organic farms achieved higher scores in any environmental and social component(with exception of the ENV_5–Energy component). On the contrary, the organic attribute doesnot seem to lead to better economic performances since in every economic component conventional farms got higher scores.

Similarly, in Fig. 2b, multifunctional farms (35 farms of the sample) achieved higherenvironmental and social scores comparing to the 15 non-multifunctional farm. These results is probably due to their direct contact with consumers (Gafsi & Favreau, 2010) that, anyway, doesn't seem to influence the economic components(scores are in accord to what found by Paracchini et al., 2015).

In Fig.2c, the SO ("Standard Output") values enable the classification of farms on the base of theireconomic size: 28 small farms, 14 medium farms and 8 large farms. The model has shown higher economic performancesof large farms with a higher value of SO. These results are in line with what found by Häni et al., 2003 andReig-Martinez et al., 2011 and it is probably due to the existence of economies of scale in agricultural productions (Álvarez & Arias, 2004) but, according to Gavrilescu et al., 2012,it hasonly some reflection in the social components (SOC_3 – Work component particularly).

Finally, in Figure 2d, the sample is has been divided into five categories of production system: 20 cereal farms, 7 livestock farms for the bovine meat production, 15 dairy farms, 4 poultry and 3 pigs livestocks). Observations could be many.In general, the economic components seem to be more influenced by individual features of farmsthat are difficult to detect by the sample's classifications. On the contrary, the environmental and the social components are more dependent from the production system of farms related to their specialization, multifunctionality and land size. In this case, a in-depth investigation of their characteristics could be more useful to identify sustainability values of farms.

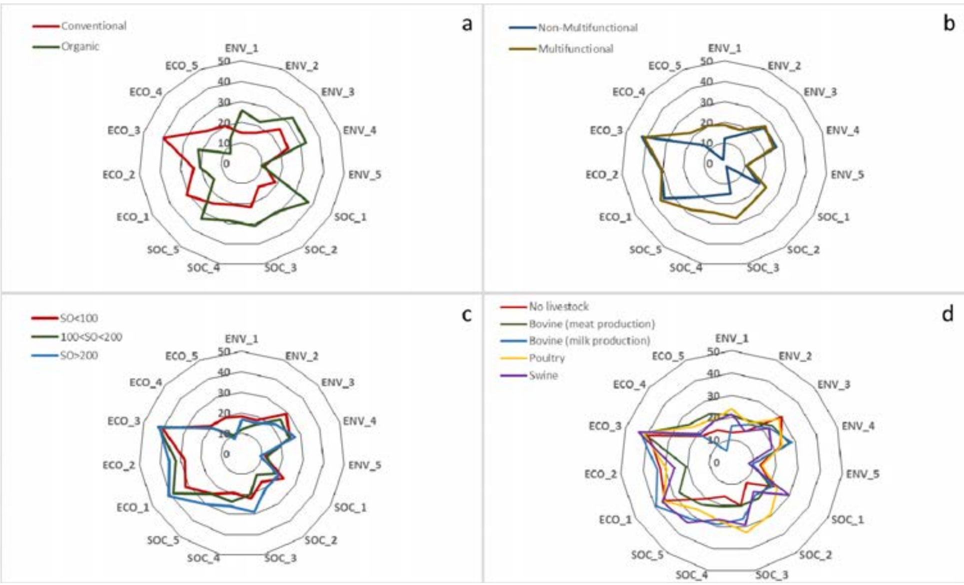

Fig. 2. Radar diagrams of (a) conventional vs organic; (b) non-multifunctional vs multifunctional; (c) small (SO<100), medium (100<SO<200), large (SO>200); (d) no livestock vs cattle (meat production) vs cattle (dairy farms) vs poultry vs pig farms' average scores

5. Conclusion

In the present work, 4Agro has been proposed as a new tool for the evaluation of performances of farms. The method seems adequate to perform an evaluation of sustainability allowing for different approaches:

- *Farms ranking*, when the case study is focused on individual farms of homogeneous groups of them;
- *Indicator (or component) evaluation*, when the assessment if focussed on single aspects of sustainability providing synthetic information to farmers who want to evaluate their levels and to know the ways to improve;
- *Score evolution* is a temporal comparison of results achieved by farms over time and those that are predictable in the future. This approach was not calculated in this research, because of the lack of data for different years.

From the methodological point of view, the study has highlighted some relevant concepts about the typical problems of availability and adequateness of information on farms' characteristics and activities. An objective of this work was to reach an ideal balancing between quality and quantity of information and their cost. The selection and the weighting of indicators processes were however arbitrary, therefore the choice remain mostly subjective. In order to evaluate the repeatability of the method proposed, as agricultural sustainability estimation procedures seem sensitive to the each particular situation, further studies might involve the application of the same method in different geographical contexts.

Acknowledgements

This research was supported by Città Metropolitana di Milano, Parco Agricolo Sud Milano, Fondazione Cariplo.

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