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# *Agricultural sustainability assessment at the farm level: an empirical analysis on the Parco Agricolo Sud Milano*

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# PREFACE

The present work has been carried out within the research project named "*Osservatorio Economico-Ambientale per l'Innovazione del Parco Agricolo Sud Milano*" (in English: Economic and Environmental Observatory for the Innovation of the South Milan Agricultural Park). The survey was carried out thanks to the collaboration with the *Città Metropolitana di Milano* (Metropolitan City of Milan), the *Parco Agricolo Sud Milano* (South Milan Agricultural Park) and the *Fondazione Cariplo* (Cariplo Foundation). The research group was composed by Mattia Bertocchi which is the author of this paper, Alberto Pirani which is the Tutor Professor and Anna Gaviglio, Eugenio Demartini and Maria Elena Marescotti.

This three-years-project has involved the creation of a new tool, named *4Agro*, able to provide the assessment of the environmental, social and economic performances of farms belonging to the region of South Milan Agricultural Park. The framework provides strategic and innovative solutions exploitable at multiple levels, from farmers to policy-makers, from researchers to ordinary citizens.

The last phase of the project will be the implementation of the theoretical framework presented in this paper in a computer tool easily accessible to any stakeholders of the study area.

# ABSTRACT

In recent years, the scientific community has offered countless approaches for the definition and the evaluation of sustainability in agriculture. Nevertheless, these tools have not yet determined the concept in a complete way. In addition, the complexity and diversity of the agricultural sector contribute to increase the difficulties. Despite these issues, there is a certain sharing in the paradigm of its multidimensionality that integrates the popular environmental goals with the economic and social rights.

Numerous studies have contributed to the definition of sustainability but only few were able to offer a common approach able to determine whether a farm is sustainable or not. For this reason researchers are frequently asked to find objective tools useful to the achievement of a shared methodological approach. This is a difficult task due to different reasons: *conceptual,* related to the difficulty of determining what is required to a farm to be defined as "sustainable", *methodological,* because of the complexity of an evaluation based on both temporal and spatial dimensions, and *politic* because of the involvement of many stakeholders with different, and sometimes even opposite, objectives.

At the farm scale, the use of quantitative indicators is particularly popular because of their ability of adaptation to different territorial systems and the use of accessible data.

This work wants to be a participation in the debate on the sustainability of farms and a contribution in the discussion about the most important methodological issues. Therefore, a tool for the assessment of environmental, social and economic performances of farms is here proposed. The aim of this work was to illustrate a new methodological process in order to formulate a framework focused on a general context, as a tool for decision support useful for farmers, policy-makers and researchers.

The work was carried out on a sample of 50 farms of the region of the South Milan Agricultural Park (PASM) that covers an area of about 40,000 hectares surrounding the city of Milan (Northern Italy). Data collection involved interviews to farmers through questionnaires, the use of the SIARL database, documents and previous projects.

The method is named *4Agro*. From the methodological point of view, the approach has been created in order to provide indexes of evaluation of each pillar of sustainability (environmental, social,

economic and a theoretical proposal for the evaluation of the institutional issues) of farms starting from their raw data. These information are then concerted in indexes by indicators, previously selected by a literature review, edited and weighted according to the objective of the case study.

The direct processing of the results, called *Farm ranking approaches*, are evaluation processes that allow the classification of different farms, homogeneous groups of them or of the same farm during time.

In order to assess the robustness of the methodological framework and to find out the presence of redundant information, a statistical analysis was carried out on the results of each indicator. Moreover, considering the critical issues related to the data availability and cost, the survey proposed a statistical approach for the indicators reduction and, consequently, the data requirement.

In conclusion, this study proposed a new framework for the assessment of farm sustainability. The survey provided some relevant methodological solution but further developments seem to be anyway needed. Firstly, the objective of finding a shared framework for different contexts is conceptually reasonable. However, methodologically, this goal requires necessary adjustments and the need of a good knowledge of the case study. Secondly, issues related to farms' data (selection, security, utilization) have raised some relevant practical problems. In the present study, a statistical approach has been proposed with the main goal to achieve a proper balance between quality and quantity of information. While the approach has proved to be methodologically appropriate, its application for the present case study has raised some important questions about the plausibility to include other quantitative variables such as the source of data and their cost. Finally, the use of *Farm ranking approaches* seemed particularly suitable to be used at different levels. Furthermore, the tool is a valuable support for policy-makers to assess the level of sustainability achieved by farmers who have adopted or who should take their policies. This research has highlighted a certain reasonableness in the proposal of assessing of a fourth scale, that could be useful in order to determine the effectiveness of the policy-makers' decisions.

# SINTESI

Negli ultimi decenni il panorama scientifico ha offerto innumerevoli approcci per la definizione e la valutazione della sostenibilità che non hanno tuttavia determinato il concetto in modo chiaro e risolutivo. In più, la complessità e l'eterogeneità del settore agricolo contribuiscono a delineare un quadro ancor più difficile. Un quadro che, seppur poco uniforme, ha spesso trovato una certa condivisione nel paradigma della sua multidimensionalità che integra i popolari obiettivi ambientali con quelli economici e sociali.

Numerosi studi hanno contribuito alla definizione di sostenibilità ma sono stati invece pochi quelli in grado di offrire un approccio condiviso per stabilire se un'azienda agricola è sostenibile o no. Per questo motivo si è frequentemente sottolineata la necessità di trovare un quadro oggettivo utile al raggiungimento di un approccio metodologico condiviso. Compito che appare particolarmente arduo per motivi *concettuali* legati alla difficoltà di stabilire cosa è richiesto all'azienda agricola per essere definita "sostenibile", *metodologici* determinati dalla complessità di una valutazione legata alle sue dimensioni spaziale e temporale, e *politici* per via del coinvolgimento di numerosi portatori d'interesse con obiettivi diversi, talvolta addirittura opposti e contrastanti.

Alla scala aziendale, l'utilizzo di indicatori quali-quantitativi è particolarmente diffuso per via della loro capacità di adattamento al sistema territoriale e della possibilità di utilizzare informazioni generalmente facili da reperire.

Il presente lavoro vuole essere una partecipazione al dibattito sul tema della sostenibilità delle aziende agricole e tende ad offrire un contributo per la discussione circa le più rilevanti questioni metodologiche che oggi sono poste alla comunità scientifica. Si propone dunque uno strumento che si colloca all'interno del vasto insieme degli approcci di valutazione della sostenibilità ambientale, sociale ed economica delle aziende agricole. L'obiettivo è quello di illustrare un nuovo processo metodologico per giungere alla formulazione di un quadro focalizzato al contesto territoriale di riferimento, quale strumento di supporto decisionale per aziende, policy-makers e ricerca.

Il lavoro è stato condotto su un campione di 50 aziende localizzate sul territorio del Parco Agricolo Sud Milano (PASM), un parco regionale che copre una superficie di circa 40,000 ha e che avvolge a cintura la città di Milano (Nord-Italia). La raccolta dei

dati aziendali ha coinvolto interviste dirette agli agricoltori tramite questionari, il database SIARL e la consultazione di documenti e progetti disponibili presso il PASM.

Il metodo creato, definito *4Agro*, è stato ideato partendo dalla consultazione degli argomenti affrontati dai più rilevanti lavori presenti nella bibliografia internazionale. Metodologicamente, l'approccio è stato creato in modo da permettere di giungere all'attribuzione di un indice di valutazione di ciascun pilastro della sostenibilità delle aziende agricole (ambientale, sociale ed economico cui si aggiunge una proposta teorica per la valutazione delle tematiche istituzionali) partendo dalla raccolta dei dati primitivi, ovvero delle caratteristiche aziendali, successivamente elaborati da indicatori propriamente selezionati, modificati e pesati in relazione del loro ruolo nella valutazione della sostenibilità per il caso di studio.

La diretta elaborazione dei risultati è rappresentata dai cosiddetti *Farm ranking approaches*, ovvero processi di valutazione che permettono di stabilire la classificazione di singole aziende agricole, gruppi omogenei di esse o delle medesime aziende in condizioni temporali successive.

Al fine di valutare la robustezza del quadro metodologico e l'eventuale presenza di informazioni ridondanti, è stata condotta in questo studio un'analisi statistica sui risultati conseguiti da ciascun indicatore. Inoltre, tenute in considerazione le criticità legate alla reperibilità ed al costo dei dati aziendali, è stata presa in esame la possibilità di ridurre il numero di indicatori e, di conseguenza, anche la quantità di informazioni necessarie.

Complessivamente, nel presente lavoro è stato proposto un nuovo metodo per la valutazione della sostenibilità delle aziende agricole. Lo studio ha offerto rilevanti spunti di discussione su alcune delle criticità metodologiche tipiche di questi tipi procedimenti. Anzitutto, l'obiettivo di formulare un quadro condiviso ed applicabile in contesti eterogenei è concettualmente ragionevole. Tuttavia, metodologicamente, questo obiettivo richiede necessari adeguamenti al contesto ambientale, sociale ed economico. In secondo luogo, le questioni legate ai dati aziendali (selezione, sicurezza, utilizzo) hanno sollevato alcune delle difficoltà più rilevanti. A tal fine, nel presente studio è stato proposto un approccio statistico per la riduzione dei dati richiesti. L'obiettivo è stato quello di giungere ad un ideale bilanciamento tra qualità e quantità di informazione e relativo costo. Se da una parte l'approccio si è dimostrato metodologicamente appropriato, l'applicazione dello stesso per il presente caso di studio ha sollevato alcune rilevanti questioni circa la plausibilità di includere ulteriori variabili quali-quantitative come la fonte dei dati e il costo degli stessi. Infine, l'indagine ha messo in luce le modalità ed i possibili approcci per la costruzione di un quadro di valutazione integrato in grado di essere compatibile al contesto ed agli obiettivi di un circoscritto ambito territoriale. L'utilizzo dei *Farm ranking approaches* è sembrato particolarmente indicato per un impiego sia aziendale che accademico. Inoltre, dal punto di vista decisionale, lo strumento si presenta come un valido supporto per i policy-makers per la valutazione dei livelli di sostenibilità raggiunti dalle aziende agricole che hanno adottato o che dovrebbero adottare le politiche intraprese dagli stessi. In tal senso, la ricerca ha permesso di evidenziare una certa ragionevolezza nella proposta di valutare una quarta scala che, potrebbe essere significativa al fine di stabilire la concreta efficacia delle scelte dei decisori stessi.

# Chapter 1.
# Sustainability in agriculture

## From the conceptualization to the assessment

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**Content of this chapter:**

The literature offers a wide range of interpretations of the concept of sustainable development and, particularly, the sustainability in agriculture. Nevertheless, there are some relevant questions related to its assessment, due both to conceptual, methodological and political issues. This work wants to be a contribution to the scientific community in finding a shared framework for the evaluation of the sustainability at the farm scale.

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## 1.1 The concept of sustainable development

Over the past decades, the discussion on sustainable development and the interest of the international community has grown considerably. Starting from the 1950s and 1960s, the concept of sustainability has began to appear thanks to the growing interest to the environmental concerns (Pretty et al., 2008). The first definition of the *sustainable development* was established in 1987 by the World Commission on Environmental and Development as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Today, this definition is still the most known even if the Brudthland Commission presented a model of sustainability reflecting only the environmental and development concerns, while the today's most shared repartition is based upon the "three bottom line" (Pope et al., 2004). In effect, according to Van Passel et al. (2007), sustainability is a holistic notion based on three pillars, economic, ecological and social, that need to be simultaneously considered to realise more sustainable human activities. However, despite its intuitive appeal, the concept of sustainability offers wide possibilities of interpretation and the debate is still very active (Park and Seaton, 1996).

As Jacobs (1996) noted, there was at least 386 definitions (up to 1996) of sustainable development. This seems to be the main weak point: the concept of "sustainability" remains a vague and elusive term (Reig-Martinez et al., 2011) and, on the consequence, the lack of agreement about a unique shared definition has led some researches (e.g. Hansen, 1996; Tait and Morris, 2000) to question the usefulness of this concept. To face these concerns, Jacob discussed the meaning of the word "democracy", to which much more definitions can be attributed, but no one denies its real usefulness. Tait and Morris (2000) tried to justify these difficulties arguing that the concept is social rather than fundamentally scientific. This observation has important implications for debated about the role of "objective" and "subjective" judgement in defining the ways of assessment of sustainability (Rigby et al., 2001). In order to avoid the lack of a concrete approach, Hueting and Reijnders (1998) argued that sustainability should be an objective concept since the definition problem is a secondary issue. In addition, the concept of sustainability continues to evolve (Bèlanger et al., 2012) and it implies an outgoing dynamic development, driven by human expectations about future opportunities (Cornelissen et al., 2001). Because of that, the nature of its concept does not represent the endpoint of a process, rather it represents the process itself (Shearman, 1990): "sustainability" is "sustainable development" (Bossel, 1999). On the consequence of this heterogeneity, the academic debate offers a multiple and even sometimes contradictory perspectives (Binder et al., 2010). Despite the wide range of interpretations, there is a certain consensus in the scientific community about the fact that definitions could be many and probably no one of them are completely wrong or completely right.

## 1.2 Conceptualizing sustainability in agriculture

The concept of sustainability in the agricultural sector is particularly popular because agriculture relates directly to the present and the future condition of environment, economies and societies (Smith and Smithers, 1993). Because of that, if considerable research efforts have been made to overcome the conceptual vagueness of sustainability, on the other hand, there is no agreement to date a common framework for its assessment (Reig-Martinez et al., 2011). On the consequence, like the concept of *sustainable development*, the term *sustainable agriculture* has been interpreted and applied in numerous ways (Smith and Smithers, 1993).

In 1996, Hansen studied the evolution of the "movement" of sustainable agriculture, at that time particularly developed in the Western countries, and he associated it to the need of response to concerns about impacts of conventional agriculture. In fact, the first studies on the evaluation of agricultural sustainability began when people started to have the perception of conventional agriculture as unsustainable (Dahlberg, 1991). From that moment, the distinction between conventional agriculture and sustainable agriculture has become more relevant in the scientific community, among people and policy-makers. Until the 1970s, increase of production was the dominant concern of those involved in agriculture and the agronomic research paid particular attention on the developing of methods able to increase the production through the use of human-made inputs (van der Werf and Petit, 2002). From that time, the critics to conventional agriculture (Thompson, 2007) because of the environmental problems mostly associated to the amount of chemicals used in the agricultural practices, and the scandals that involved the agricultural sector, contributed to the consciousness of the need of a change (Rembiałkowska, 2004). More recently, worries about a loss of quality of the source functions of natural capital for agriculture have received increasing attention (van der Werf and Petit, 2002). In those years, *conventional agriculture* has been described as intensive, large-scale, highly mechanized with monocultures, high use of artificial fertilizers and pesticides and intensive animal husbandry (Hansen, 1996). This definition was in complete contrast with the one attributed to the *sustainable agriculture*. This was a very general concept that included all the alternative approaches to agriculture, such as organic farming, extensive agriculture, low-input agriculture, biodynamic agriculture, permaculture, agroecology and so on (Carter, 1989; Bidwell, 1986; Dalhlberg, 1991; Hansen, 1996; Pretty, 2008). This was the typical approach of the first years after the earliest definitions of sustainability that, without the availability of specific parameters of evaluation, tended to attribute the concept of sustainability to all the alternative systems of production. Nevertheless, the statement that alternative agriculture is beforehand more sustainable than the conventional one does not add any contribution to the discussion about sustainability and it subtracts the need of definition of sustainability itself. Because of that, some researchers tried to explain agricultural sustainability by the association of typical attributes of those types of alternative agriculture, in particular the reduction or elimination of the use of processed chemicals, decentralization, independence, harmony with nature and communities (Hansen, 1996). Other studies (Bidwell, 1986; Francis and Youngberg, 1990) went beyond strictly the environmental issue and introduced social and economic values, such as equity, traditionalism, self-sufficiency and culture. These efforts have contributed to separate the concept of sustainability from the one of alternative agriculture and, at the same time, the concept of unsustainability from the one of conventional agriculture.

The lack of a close association between a concept and its real application has contributed to raise the debate about a shared definition of sustainable agriculture. On the consequence, a unique definition seems difficult to share as sustainability means different things to different people. As some believe that, for example, organic farming and sustainable agriculture are synonymous, and therefore there is no need to find further solutions, others believe that conventional agriculture is just fine as it is, and there is no need for special programmes on sustainable agriculture (Rigby and Cáceres, 2001; Thompson, 2007).

This lack of shared knowledge has led to the formulation of many definitions, but often general or not very comprehensive. Since the first attempts, the concept of sustainable agriculture has been interpreted and applied in various ways, in relation to the study area, the scale of analysis and the objective of the survey (Binder et al., 2010). Some first definitions of the end of the 1980s and the beginning of the 1990s seem to be still valid. Crosson (1992) described a sustainable agricultural systems as one "that can indefinitely meet demands for food and fibre at socially acceptable economic and environmental costs". This definition integrated the three pillars but more importance seems to be attributed to the satisfaction of the food demand, still today a great challenge of the international community. Even earlier, Francis and Youngberg (1990) described a philosophy based on human goals, with particular regard for the environmental and social aspects, where sustainable agriculture should leads to "integrated, resource conserving, equitable farming systems which reduce environmental degradation, maintain agricultural productivity, promote economic viability in both the short and long term, and maintain stable rural communities and quality of life". Other definitions seems to be today less useful. Repetto (1987) gave a more economic view of what sustainability should be, attributing to the other two dimensions less importance: in this case, sustainable agriculture was considered in terms of the adequacy of economic returns to farming relative to the costs of production, and of the prospects for continuing economic viability in the face of changing environmental, social, and economic conditions. There were also some studies that illustrated the social importance of the agriculture with the focus on the future of rural farming communities (Marsden et al., 1989; Ilbery, 1991). These concepts have been examined in terms of the survival or demise of family farms, and adjustments in production activities, labour and capital. Adapting the concept of sustainable development, Hansen (1996) defined as sustainable an agricultural activity that permanently satisfies a given set of condition for an indefinite period of time. More recently, Lewandowski et al. (1999) has provided a rather exhaustive definition of sustainable agriculture as "the management and utilization of the agricultural ecosystem in a way that maintains its biological diversity, productivity, regeneration capacity, vitality, and ability to function, so that it can fulfil – today and in the future – significant ecological, economic and social functions at the local, national and global levels and does not harm other ecosystems".

Despite the wide range of definitions, today's most important challenge seems to be in finding of a shared framework for evaluation and the creation of a set of tools able to direct agricultural choices towards innovation and sustainability. In fact, rather than seeking a single definition and model of sustainable agriculture, it seems more appropriate the researching of frameworks and solutions to improve the sustainability in agriculture.

## 1.3 Relevant issues related to the assessment of sustainability in agriculture

Since the definition of sustainability is useful for consolidating concerns and motivating change, concrete attempts of its application as an operational tool for guiding efforts to improve agricultural systems are difficult to identify (Verbruggen et al., 1991; Hansen, 1996).

There is a clear difficulty in conceptualization of agricultural sustainability but, according to Gómez-Limón and Sanchez-Fernandez (2010) and Hueting and Reijnders (1998), its operational concretization could involve more relevant problems. Three are the main issues. Firstly, as sustainability consistently means "continuity through time" (Cornelissen et al., 2001), attempts of assessment need for an analysis of the future agricultural production, a requirement that is difficult to observe in any reasonable time horizon (Gómez-Limón and Riesgo, 2009). Secondly, it is difficult to identify what specific demands agriculture needs to satisfy in order to be sustainable, as there are many answers to this question. Sustainability thus needs to be understood largely as a social construction (Tait and Morris, 2000) which changes as a function of society and thus needs to be specifically formulated for any given set of geographical and temporal conditions. Lastly, operational definition of sustainable agriculture is extremely problematic because of the large number of parties involved in the debated, from researcher to farmers, from people to politicians (Rigby and Cáceres, 2001). All these problems have long made it difficult to convert the concept of sustainability to an operational tool for guiding agricultural development.

On the consequence, today's idea of agricultural sustainability does not mean ruling out any technologies or practices on ideal grounds (Pretty, 2008) and the scientific community should resist the temptation of designing sustainable systems as such (Tait and Morris, 2000). In order to bypass these issues, some studies (e.g.

Smith and McDonald, 1993) argued that these limiting factors should lead to the development of inverse approaches, in order to assess the unsustainable development. In addition, the need of involvement of the three dimension of sustainability in a unique pattern has contributed to the multifunctionality of the concept of sustainability. This causes a larger complexity that needs to be evaluated as a whole, because great performance in one side could mean worst results in another. As asked by Pretty (2008), if environmental goods are to be protected or improved even accepting a decrease of productivity (with consequent social issues), the need of more agricultural land (and thus the loss of natural capital) is justified in order to seek of sustainable production? Is this a sustainable approach?

In order to avoid to fall in this contradictions, and despite an alight discussion on the meaning of the concept of sustainable agriculture, nowadays there is a wide convergence on his multidimensional character related to the environmental, social and economic perspectives (Yunlong and Smit, 1994; Goodland, 1995; Gómez-Limón and Sanchez-Fernandez, 2010).

## 1.4 The objective of the research

This dissertation is inspired by the need to address sustainability of agriculture from an objective perspective. This commitment called attention to the notion of environmental, social and economic sustainability and the creation of a new methodology for the assessment of sustainability at the farm scale. In the following sections, the concept of sustainability is developed with a literature review and with an in-depth analysis of the available methodologies. The following sections explain the methodology and the case study, the results and the discussion of the outcome of the survey and, finally, the last section is a concluding paragraph in order to offer a summary of the research and some reflections on its potentialities and limitations.

# Chapter 2.
# The assessment of sustainability in agriculture

**Content of this chapter:**

The work has started from a in-depth overview of the available methodologies for the assessment of agricultural sustainability at the farm scale. The literature is particularly rich of content related to the environmental and ecological concerns and the economic issues, while the social implications are less discussed. Recently, this three-pillars approach has found a new framework that integrates the role of the institutions, which are able to contribute to the improvement of the environmental, social and economic performances of farms. Despite this shared knowledges, some relevant methodological questions still remain without a complete answer.

## 2.1 An overview of the available methodologies for the assessment of agricultural sustainability at the farm scale

The development of decision-support tools is essential in guiding agriculture towards sustainability (Hansen, 1996). Therefore, the main purpose of sustainability assessment is to provide an evaluation of integrated nature-society systems in order to assist them to determine which actions should or not should be taken in an attempt to make society sustainable (Kates et al., 2001). This framework involves the capability to measure all the impacts (economic, social and environmental) generated by agriculture activities (Andreoli and Tellarini, 2000). Nevertheless, putting the theoretical concept into practice often proves to be very difficult (Meul et al., 2008).

The recognition of the existence of several assessment tools for sustainability evaluation of agricultural production systems and the observance of a large variability to support policy-making give relevance to this research question (Binder et al., 2010). Because of that and because of the crescent interest in the community, sustainability assessment has become a key issue, both for academia, farmers and policy-makers (Pacini et al., 2004). These issues are particularly popular in Europe where the community shows expertise and leadership in evaluating sustainability since changes occur within the environmental context and farmers need to adjust their practices to move toward sustainability, because of the obligation imposed by the EU regulation (Bezlepkina et al., 2011).

In the process of selection of the assessment approach, many factors affect the choice, starting from the scale of the analysis and the objective of the research, the data availability and the space and temporal factors (Freebairn and King, 2003). From the scientific point of view, the discussion should deal with the best way of assessment in order to find the best alternative solution for the area of analysis. This strictly depends from the case study.

The literature offers approaches at different spatial scales, ranging from field and farm to regional, national, and even international scale (Hansen, 1996, Jacobs, 1995; Smith and McDonald, 1998). As before said, the choice of scale of analysis is strictly dependent of the objective of the survey. Researchers that opted for a farm/local scale in their studies (Van der Werf and Petit, 2002; Häni et al., 2003; Pacini et al., 2004; Rasul and Thapa, 2004; Van Cauwenbergh et al., 2007; Meul et al., 2008; Vilain et al., 2008; Gómez Limón and Riesgo, 2009; Reig-Martinez et al., 2011; Paracchini et al., 2015; Thiollet-Scholtus et al., 2015) took advantage of the possibility of an in-depth investigation of farm dynamics, while research studies that used a regional/territorial scale (Paracchini et al., 2011; Mazzocchi et al., 2013; Demartini et al., 2015) could limit the cost of analysis, ensuring transparency of data and repeatability of measurements (Demartini et al., 2015).

Nevertheless, although there is a consensus on how to evaluate and implement sustainable agriculture at the policy level, assessment of sustainability at the farm level is not well-established (Singh et al., 2009; Bélanger et al., 2012).

The recognition of the need of a shared definition of sustainability at the farm scale has led to the formulation of numerous frameworks of assessment often composed by indicators (Bockstaller et al., 1997; Panell and Glenn, 2000). At this level, sustainability indicators are tools that can be used by farmers to assess the effects of managerial changes, but they are also useful for researchers and policy-makers that need to identify agricultural sustainable practices and the farm's characteristics that mostly influence sustainability (Pannell and Glenn, 2000; Häni et al., 2003; Van Cauwenbergh et al., 2007). Agricultural sustainability indicators are instruments that (i) use a set of data in order to (ii) quantify the information through simplification (Girardin et al., 1999; Mitchell et al., 1995, Rigby et al., 2001; Singh et al., 2009) and (iii) to offer an easy communication (Bélanger et al., 2012) useful at the multiple level (Girardin et al., 2000). The term indicator has been defined as a variable that supplies information on other variables which are difficult to assess (Mitchell et al., 1995).

The literature offers a wide range of approaches and possible applications at the farm level through the use of indicators. These include, among others:

- single indicators focussed in particular themes of sustainability are able to offer an in-depth analysis of single aspects of sustainability. Pereira et al. (2012) proposed the use of specific indicators in order to assess the water use performance of farms and the ways for a more sustainable water conservation and saving. Castoldi et al. (2009) studied the performance of the use of phosphorus in the farms through an approach at the regional scale;

- indicator lists that include separate approaches (Girardin et al., 2000). These works are useful to provide a set of tools in order to choose the appropriate indicators in relation to the objectives of the analysis;
- assessment of production alternatives through the Life Cycle Assessment (LCA). Audsley et al. (1997) presented an application of LCA to agricultural production through a study conducted on three different methods of growing wheat. Garrigues et al. (2012) worked on the development of an indicator of soil quality through LCA;
- indexes are relevant instruments able to provide a synthetized framework of the situation and they are useful for policy-makers and the community because they can easily represent a complex condition. Mayrhofer et al., 1996 proposed a tool called Ecopoints, a method that assigns scores to farmer production practices and landscapes maintenance.

This approach favoured farmers that adopted environmental-friendly practices through an adequate level of payment. When indicators are not used individually, they can be viewed as a part of a set, or aggregated within a set in order to offer an exhaustive assessment of sustainability (Van Passel et al., 2007):

- single-pillars assessments are studies that focus only on one of the three pillar of sustainability. The environmental assessment is particularly diffused. The INDIGO Method (Thiollet-Scholtus and Bockstaller, 2015) uses a set of 4 specific indicators concentrated on the environmental impact of farms. This brand new method is still in development and the authors have planned to complete it with the evaluation of other two pillars of sustainability. Bélanger et al. (2012) presented a 13-indicator based method in order to evaluate the agri-environmental performance of Canadian dairy farms. Thivierge et al. (2014) applicated similar indicators to crop farm of the same study area. The economic sustainability assessments are relatively diffuses. Pannel and Glenn (2000) focussed their work on the economic valuation through a selection of the most relevant sustainability indicators. Despite there is a wide range of approaches able to assess the environmental or the economic pillar of sustainability, till today no one work has been published in order to evaluate exclusively the social pillar;

- partially integrate approaches are able to evaluate a set of themes related to the environmental, economic and social sustainability of agriculture providing a partial exhaustive analysis that focus on a series of factors particularly interesting for the study area. Castoldi and Bechini (2010) proposed a method based in 15 economic and environmental indicators of cropping systems in northern Italy; the work didn't involve the social themes. Paracchini et al. (2015) created a tool, called SOSTARE, that assesses the ecological, agronomic and economic performance of farms of the Parco del Ticino (Italy), without taking into account the social pillar of sustainability. Van Cauwenbergh et al. (2007) developed SAFE (Sustainability assessment of Farming and the Environment) that used a three-pillar approach that didn't consider any principle of equity between the three pillars; as a result, the social pillar seems to get a less importance. Häni et al. (2003) performed the RISE (Response-inducting Sustainability Evaluation) method, a tool able to evaluate 57 environmental, social and economic parameters that however didn't consider the three-pillar approach. Bonneau et al. (2014a) proposed an integrate approach for the evaluation of sustainability of pig farms. The group of research presented a series of articles (Bonneau et al., 2014a; Bonneau et al., 2014b; Ilari-Antoine et al., 2014; Rydhmer et al., 2014) that provide a complete set of environmental, social and economic assessment, strictly focussed on pig farming systems;
- full-integrate approaches that measure the level of environmental, social and economic sustainability of farms, attributing them an equal importance, in accordance to the modern model of the concept of sustainability. Meul et al. (2008) proposed one of the first instruments that provide an approach based on the equal importance of the three pillars. Until today, the method, called MOTIFS, has been used only for dairy farms. Vilain at al. (2008) created La méthode IDEA (Indicateurs de Durabilité des Exploitations Agricoles). This tool has been adopted in various studies (e.g. Fortun-Lamothe et al., 2009; Marie et al., 2009; Gafsi and Favreau, 2010; Elfkih et al., 2012; Gavrilescu et al., 2012; Benidir et al., 2013) because of his capacity to be adaptable in different territorial context. The method assesses the farm performance through the use of 42 indicators that pro-

vide an equal attribution to the importance of the three pillars. Data are based both on quantitative and qualitative parameters. Reig-Martínez et al. (2011) created and approach based on the evaluation of the three pillars that combines Data Envelopment Analysis (DEA) and Multicriteria Decision Making (MCDM) in order to create a ranking of the farms in the respective study area.

This overview of methods and tools is not exhaustive but it is helpful to understand the wide range of approaches available at the farm scale. On the consequence, numerous works have also focused their study on the critical of these instruments. The literature offers a wide range of reflections and considerations in order to find out their main shortcomings. Among these, the main points can be summarized as follow:

- although the environmental, social and economic pillars of sustainability are linked to each other and methods that aim at the development of this type of framework are numerous, a complete integrated approach seems to be difficult (Wells, 2001; Zimmerer and Basset, 2003). This also involves problems of data requirement and incommensurability between different facets or dimensions of sustainability. For some (Rigby et al., 2001), these issues become stronger as the analysis moves to the system beyond the farm boundaries;
- even in the case of an integrated approach, different pillars have attracted varying levels of attention (Singh et al., 2009). In fact, in modelling and assessment, there is an imbalance regarding the ecological, economic and social dimensions of sustainability, insofar as the ecological aspect is favoured (von Wirén-Lehr, 2001; Binder et al., 2010; Chatzinikolaou et al., 2012) probably because of the growing social sensitivity of the community to ecological issues. On the other hand, the evaluation of economic and, especially, social sustainability suffers from a lack of accepted and wellgrounded frameworks (Chatzinikolaou et al. 2012);
- research has so far theorized the sustainability assessment focussing on filling important gaps in knowledge and technology, but has neglected the step towards utilization and implementation of this knowledge (Binder et al., 2010);

- difficulties involve the combination of indicators required for such analyses, which is an obstacle to use these as a practical public decision-support tool (Gómez-Limón and Sanchez Fernandez, 2010);
- the quantification of agricultural sustainability using indicators still shows operational problems. These problems are particularly relevant when the context of analysis is complex, such as in agriculture. In particular, the diversity of production, types of farms and the economic, social and environmental issues make difficult the creation of a unique framework of evaluation.

In the following sections, the literature review focusses on the themes related to the three pillars of sustainability.

## 2.2 The environmental and ecological concerns

Despite the wide diversity of interpretations, there is shared agreement in the fact that the environmental dimension of sustainability is fundamental to overall sustainability, as it is a prerequisite for the economic and social ones (van der Werf and Petit, 2002).

Limiting environmental impact to an acceptable level became increasingly important in agriculture research even before the conceptualization of sustainability. In the intensive agriculture, farmers regulate their management practices in order to find the optimal combination of inputs based on natural capital and those from human-made capital, providing desired products and undesired emissions to the environment (Van der Werf and Petit, 2002). Anthropogenic factors, such as agrochemical contamination, pesticide poisoning of non-target organisms, soil loss, depletion of water resources, emissions of greenhouse gases and loss of biodiversity has led to the need of studying sustainability in a holistic way (Pacini et al., 2003). These "disservices" are largely dependent on the amplified value given in the past to economic component of agricultural production (Van der Werf and Petit, 2002).

The environmental sustainability has involved many attempts of explanations. Some of them, such as Hauptli et al. (1990), used a principle of similarity to the nature according to which "…sustainable agriculture attempts to mimic the key characteristics of a natural ecosystem…" Thus, sustainable agriculture can be defined as the ability of agroecosystems to remain productive in the long term, maintaining their biological diversity and regeneration capacity (Van der Werf and Petit, 2002; Van Cauwenbergh et al., 2007). Goodland (1995) defined the environmental sustainability as "the maintenance of natural resources, which comprises the resources providing sink and source functions in ecosystems". At the farm level, Van Cauwenbergh et al. (2007) defined an agricultural system as sustainable if it conserves the natural resources provided by ecosystem. By this way, natural resources can be expressed as environmental objectives: water, soil and air quality and the maintenance of biodiversity (Girardin et al., 2000).

On the consequence, it seems clear that agriculture and natural ecosystem are strictly interconnected and farmers are asked to not only provide foods and services to humans, but also to preserve natural resources (Dale and Polasky, 2007).

Therefore, literature offers a wide range of interpretations and ways of assessment. Many attempts to address environmental sustainability have been made from the Rio Earth Summit (1992). The scientific community has been challenged in finding theories and procedure in order to establish techniques that combine adequate production with a more sustainable environmental impact (Thivierge et al., 2014). Today it is no longer acceptable to introduce environmental policies unless a programme of evaluation (Girardin et al., 2000). As outlined in the Paragraph 2.1, this consciousness is particularly developed in Europe, where the Common Agricultural Policy (CAP) gave a boost in the direction of the environmental safeguard by the "agro-environmental payments" which were incorporated into the second pillar of the CAP, the Rural Development Plan (RDP). Since the Agenda 2000 reform, the CAP has introduced payment methods aimed at the compensation of farmers for any income losses caused by the use of more environmentally friendly practices. Few years later, the Fishler reform established the decoupling of farms income support from production and pushed towards the efficient delivery of environmental services (Baylis et al, 2008). Hence, farmers were required to meet minimum environmental standard before becoming eligible for any farm payment. More recently, the new CAP reform has introduced the "Greening" parameters that integrated the environmental safeguard in the first pillar. Particular attention has been paid to the biodiversity, the landscape management and the diversity of production. Despite the real utility of these instruments, it is also clear that the efficiency and effectiveness of CAP reforms are impossible to verify without a scientific evaluation of their ability to enhance sustainability of agroecosystems (Pacini et al., 2004).

At the farm scale, the linkage between the environmental effects and the farming practices is however indirect, as the environmental impact depends from the farming system, which in turn depends of farmer production practices but also on random factors (van der Werf and Petit, 2002). Because of that, the direct assessment of the environmental status of farm resources may be the best approach for assessing sustainability (Bélanger et al., 2012). However, this approach is often too expensive and technically difficult to implement (Girardin et al., 1999). On the consequence, the use of indicators could be more useful when data detectably through direct measurement is not available.

Table 2.1 (page 24) at the end of this chapter provides an overview of the main environmental themes selected from the literature review.

## 2.3 Social implications

Contemporary society recognizes agriculture as having important responsibility in safeguarding the region, its culture and traditions (Gaviglio et al., 2014a). Nevertheless, among the discussions about the evaluation of sustainability in agriculture, the social dimension have often received less attention than the environmental and economic ones (Bacon et al., 2012; Chatzinikolaou et al., 2012). On the consequence, little or no scientific information are available (Meul et al., 2008). These issues has caused a certain difficulty in finding a shared framework among the scientific community and policy-makers. Both conceptual and methodological motivations are involved in this context. In the first case, perception of social issues is heterogeneous and this causes a lack of conceptual clarity (Omann and Spangenberg, 2002). In addition, this consideration leads to believe that the assessment of social sustainability is particularly dependent on the local context and its socio-political goals (Littig and Griessier, 2005). This cause a significant difficulty in finding a match between the social objectives and their corresponding methods of assessment (Omann and Spangenberg, 2002).

From the methodological point of view, literature is avaricious of approaches that seek to evaluate the social agricultural sustainability. Essentially, there is an absolute lack of works based on the unique assessment of the social dimension. Even when scientists suggest a great number of social indicators they still hesitate to formulate normative targets (Omann and Spangenberg, 2002). Among the integrated approaches, some methods (Castoldi and

Bechini, 2010; Paracchini et al., 2015) only evaluated the economic and environmental dimensions of sustainability. The three-pillars based approaches often treat the social pillar using qualitative assessments, based on observations and opinions or indicators that require difficult to find data (Häni et al., 2003; Van Cauwenbergh et al., 2007; Meul et al., 2008; Vilain et al., 2008; Zahm et al., 2008). On the consequence, less or secondary importance seems to be attributed to this pillar.

This is a significant lack because this dimension is essential to the concept of sustainable development. Because of that, the purpose of offering a quantitative assessment of social sustainability is a challenging task.

Despite these issues and even if the concept of social sustainability is particularly dependent of the objective of the research and the geographical context, the literature offers a sufficiently wide range of social issues that involve the agricultural context. Table 2.2 (page 25) reports the main themes.

## 2.4 The economic issues

Economic sustainability is what contributes to make a farming system perennial. The property of resilience is the feature for a farm to be able to continue operating in the future (Lien et al., 2007). This involves the capacity of a farm to survive various risks and shocks and therefore, studies on farm sustainability need to integrate their dynamic nature.

In many studies, economic sustainability is often confined to assessment of its viability. However, the scope of an economic tool should also comprehend the assessments of other characteristics, such as efficiency, transferability, diversification, multifunctionality (Zahm et al., 2008). Therefore, it seems essential to consider the global economic health and profitability of the farm. To reach this main goal, a farm should be able to provide an income allowing the farmer to reach his economic aims and to be able to work in a viable farm (Bonneau et al., 2014a).

These aspects has become more relevant in the last decade, with the reduction of public support for agriculture adopted by the CAP that has forced the adaptation of farms to market dynamics, with reflections to their efficiency and profitability. Because of these recent developments, farmers are required to take decisions that go beyond the strictly productive management. Therefore, new skills, such as the marketing and managerial choices, are required. Among the possible options, diversification of farm activities, products and services plays an important role in trying in maintaining a certain level of competitiveness and profitability, compared to the traditional production of agricultural commodities (Grande, 2011).

In addition, the crescent interest of the community towards the close interdependence between agriculture, the environment and the management of rural areas have become covered in the concept of multifunctionality. This notion strengthens the role of agriculture in providing environmental services and preserve natural capitals and, at the same time, to offer income diversification opportunities to farmers (Costanza et al., 1997).

Table 2.3 (page 26) shows the main economic sustainability themes selected from the literature review.

## 2.5 The role of the governance

In recent years, researches have established the formulation of a new framework that integrates a fourth scale of sustainability, often defined as "governance" or "institutional". This approach aims at the provision of an integrated framework able to assess the connections between the productive sector and institutions. The evaluation of this new dimension has been performed for many productive sectors, but its application in agriculture is still lacking. Nevertheless, it seems clear that an assessment at the farm level is undoubtedly difficult, since the issues are multiple and heterogeneous. In fact, in the agricultural sector, the relationships between farms and institutions are very relevant because the ways in which public decision-makers attempt to address the “governance” of the whole agricultural sector have their most direct impact on farms (Van Passel et al., 2007). This involves two separate levels: local and European. Firstly, farms are highly dependent on the local context and policy decision daily affect positively or negatively the farm's income, the rural society and the environmental conditions. Secondly, even if the farm's dependence from the EU contributions is progressively decreasing, the adoption of strict conditions that associate founds to the farm's decisions in social and environmental fields, both mandatory (see the "Greening" parameters) and facultative (see the "Rural Development Plan", RPD), induces to a relevant connection between farms and institution.

## 2.6 Relevant questions in the application of an integrated framework for the assessment of the sustainability at the farm scale

The construction of an integrated approach has the objective of the evaluation of the environmental, social and economic sustainability using the principle of equity between pillars.
The lack of a shared framework for the sustainability assessment at the farm scale often forces the researchers to an arbitrary choice of indicators (Van Cauwenbergh et al. 2007). Some researchers (Van Calker et al., 2005; Meul et al., 2008) suggest that it is best to develop a set of indicators for specific production systems and geographical context. In this case, a proper balance between the data availability and the significance of the information is a key point for the construction of the method. These considerations lead to the consciousness that the use of a unique method useful for any context and able to assess the farm sustainability with heterogeneous characteristics has shown some relevant questions:

- (i) according to Zahm et al. (2008), the need of sharing a unique approach useful in agricultural systems in different geographical contexts of the world seems to be hard, if not impossible, to reach. As the environmental, social and economic conditions are deeply different from the Mediterranean to boreal climates, even the sustainability's goals are very differentiate. This consideration is even more relevant in consideration of the dynamic characteristics of the concept of sustainability that, as reported in Paragraph 1.1 should be considered as a process. By this way, different starting levels of sustainability of different areas imply the arrangement of different objectives. Is it reasonable the creation of a unique framework able to assess sustainability in different environmental, social and economic contexts?
- (ii) the heterogeneity of the agricultural characteristics of farms involves some questions, starting from their specialization. Is it possible the evaluation of different types of farm (e.g. livestock farms, rice farms, horticultural farms and so on), using a single approach?
- (iii) the objective of the evaluation of the overall sustainability is a challenging task but it implies the acceptance of the losing of some information. The researchers should have the capacity to balance the quantitative of data and the quality

of the outputs. In this case, is the loss of potentially important information justified by the need of the construction of a integrate three-pillar approach?

- (iv) unlike the larger spatial scales such as the regional or national level, a weak point of the analysis at the farm scale is often the availability and the certainty of the data sources. The selection of the indicators cannot disregard from this starting point. In fact, dealing with farm data, mainly achieved from questionnaire and interviews is a sensitive aspect. In this case, an appropriate balance between the meaningfulness of the indicator and the data requirement is fundamental. How to evaluate when it is preferable the use of secure and accurate data for the calculation of simple indicator rather than the use of complex approaches using uncertain data sources?
- (v) finally, the construction of an integrated approach also means providing useful output at multiple levels, from farmers to policy-makers, from researchers to the public. How is it possible to reconcile these objectives in one approach?

## 2.7 A theoretical approach: the IDEA experience

In order to answer to questions of Paragraph 2.6, Vilain et al. (2008) and Zahm et al. (2008) proposed an integrated approach based on both quantitative and qualitative indicators. The IDEA Method provides the basis for the assessment of the sustainability at the farm level using easy-to-find data. The framework is based on 42 indicators organized into 10 components covering the three scales of sustainability. The method adopts a rating system that assigns a pre-determined upper limit for each indicator and component and an upper limit of 100 points to each scale. The calculation method is based on a data reduction, from primitive data to indicators, components and, lastly, the three scales of sustainability. Two are the main principles. Firstly, the compensation between criteria in the same component. Indeed, the score value of each component is the cumulative score of indicators. This score is limited to a certain value. Therefore, within the same scale, the full sustainability value is the cumulative of components scores and has an upper limit of 100 points. Thus, favourable practices will offset practices with a harmful effect on another component. Secondly, the method adopts the rule of key constraints: the lowest value of the three scales is used as the final numerical sustainability. This principle could seem contradictory but, according to Viaux (2003) and Zahm et al. (2006), the use of an all-inclusive single score based on a combination of the three scales would have no real meaning, as it would allow compensation across the three scales.

In this study, the theoretical framework of the IDEA Method was evaluated in order to find an appropriate assessment of the sustainability of farm of the case study. The first step was the construction of the IDEA's framework from the theoretical information (available from Vilain et al., 2008) to a calculation model (database and calculation base were constructed using Microsoft Office Excel). Five farms of the sample (see the following Paragraph 3.4) were selected and tested in order to find out the possible methodological weak point and the data availability for the case study. This phase has shown some relevant issues about the IDEA framework:

- the method is easily applied at the farm scale and it provides quantitative information concerning the three sustainability scales;
- the estimation of indicators is easy and it is facilitated by a direct farm survey. The information obtained through questionnaire permit an easy calculation of scores corresponding to each indicator;
- the main methodological problem seems to be the low significance of some indicators. In particular, the social assessment is essentially based on qualitative assessments than placed into quantitative frameworks;
- since the method was initially designed to be applied to French case studies, a direct application of this method, without any adaptation, to another context or another geopolitical area may lead to biased results (Zahm et al., 2008; Marie et al., 2009; Elfkih et al., 2012). In addition, the lack of data to assess some indicators makes its integral application difficult;
- the adaptation of the method for different production systems involves relevant methodological concerns, and authors don't give any suggestion in this field.

The study on the IDEA Method has highlighted its robustness but it also underlined the inapplicability of the method itself to the local context and the analysis objectives of the present survey.

*Table 2.1: Proposed criteria for assessing the environmental dimension of sustainability at the farm level.*

| Themes | Selected variables for analysis | Selected authors |
|---|---|---|
| Soil management | Soil cover, soil loss, soil chemical and physical quality, soil contamination, soil quality, tilled area, organic matter content | *Häni et al., 2003; Van Cauwenbergh et al., 2007; Meul et al., 2008; Vilain et al., 2008; Reig-Martínez et al., 2011; Bélanger et al., 2012; Thivierge et al., 2014; Thiollet and Bockstaller, 2015* |
| Energy | Energy balance, energy use efficiency, energy output | *Häni et al., 2003; Van Cauwenbergh et al., 2007; Meul et al., 2008; Castoldi and Bechini., 2010; Reig-Martínez et al., 2011; Paracchini et al., 2015; Thiollet and Bockstaller, 2015* |
| Farming practices | Nitrogen balance, Phosphorus balance, Potassium balance, pesticide risk, crop rotation | *Häni et al., 2003; Meul et al., 2008; Vilain et al., 2008; Castoldi and Bechini, 2010; Reig-Martínez et al., 2011; Bélanger et al., 2012; Thivierge et al., 2014, Paracchini et al., 2015; Thiollet and Bockstaller, 2015* |
| Landscape management | Agroenvironmental subsidy areas, functional landscapes pattern, natural value of the farm | *Vilain et al., 2008; Reig-Martínez et al., 2011; Paracchini et al., 2015* |
| Air management | Air quality | *Van Cauwenbergh et al., 2007; Vilain et al., 2008* |
| Water management | Water consumption, water use efficiency, water quality | *Häni et al., 2003; Van Cauwenbergh et al., 2007; Meul et al., 2008; Vilain et al., 2008; Paracchini et al., 2015* |
| Biodiversity | Zones of ecological compensation, genetic diversity, species diversity, habitat diversity | *Häni et al., 2003; Van Cauwenbergh et al., 2007; Meul et al., 2008; Vilain et al., 2008* |
| Wastes management | Wastes produced | *Häni et al., 2003* |

*Table 2.2: Proposed criteria for assessing the social dimension of sustainability at the farm level*

| Themes | Selected variables for analysis | Selected authors |
|---|---|---|
| Work | Stability of the workforce, working conditions | *Häni et al., 2003; Van Cauwenbergh et al., 2007; Vilain et al., 2008; Gómez-Limón and Fernandez 2010; Paracchini et al., 2011; Reig-Martínez et al., 2011; Bacon et al., 2012; Bonneau et al., 2014* |
| Culture | Education, cultural acceptability | *Van Cauwenbergh et al., 2007; Paracchini et al., 2011; Bacon et al., 2012* |
| Persistence on the territory | Resiliency, vulnerability, risk of abandon of the agricultural activity | *Häni et al., 2003; Van Cauwenbergh et al., 2007; Vilain et al., 2008; Reig-Martínez et al., 2011; Bacon et al., 2012* |
| Stability of the rural population | Economic dependence on agricultural activity | *Meul et al., 2008; Reig-Martínez et al., 2011* |
| Human health | Food security and safety | *Häni et al., 2003 ; Van Cauwenbergh et al., 2007; Vilain et al., 2008; Paracchini et al., 2011; Bacon et al., 2012 ; Bonneau et al., 2014* |
| Animal health and welfare | Breeding conditions | *Meul et al., 2008; Vilain et al., 2008; Bonneau et al., 2014* |
| Quality of life | Life expectancy | *Van Cauwenbergh et al., 2007; Vilain et al., 2008; Bacon et al., 2012* |
| Equity, justice and integration | Recreation | *Häni et al., 2003; Paracchini et al., 2011; Bacon et al., 2012* |
| Landscape management | Valorisation of the landscape heritage, space accessibility, architecture | *Meul et al., 2008* |
| Quality of the products and region | Quality certified food products, organic farming | *Meul et al., 2008; Vilain et al., 2008* |
| Local economy | Short chains (SFSCs), direct sale | *Häni et al., 2003; Vilain et al., 2008* |

*Table 2.3: Proposed criteria for assessing the economic dimension of sustainability at the farm level*

| **Themes** | **Selected variables for analysis** | **Selected authors** |
|---|---|---|
| Viability | Income of agricultural producers, efficiency, transferability, cash flow, investments, productivity, profitably, value of production, value added, farm household income, gross income, gross margin, variable cost | *Häni et al., 2003; Van Cauwenbergh et al., 2007; Meul et al., 2008; Vilain et al., 2008; Castoldi and Bechini, 2010; Paracchini et al., 2011; Reig-Martínez et al., 2011; Bonneau et al., 2014; Paracchini et al., 2015* |
| Safety | Insured area | *Reig-Martínez et al., 2011* |
| Autonomy | Financial autonomy | *Bonneau et al., 2014* |
| Independence | Independence from the CAP subsides | *Van Cauwenbergh et al., 2007; Vilain et al., 2008; Paracchini et al., 2015* |
| Diversification | Farm business diversification | *Paracchini et al., 2015* |

# Chapter 3.

## The integrated assessment of the farm sustainability

**Content of this chapter:**

The study introduces *4Agro*, a new framework for the assessment of the environmental, social and economic sustainability of farms. Furthermore, a theoretical proposal for the evaluation of the governance pillar is here developed. The method has been tested on 50 farms belonging to the South Milan Agricultural Park. The outputs of the method allow the use of the so-called *Farm ranking approaches*, while a statistical analysis has been carried out in order to find out some possible improvement of the methodological framework.

## 3.1 From the theory to the practice. 4Agro: the proposed framework

*4Agro* is an indicator-based method that aims at the assessment of environmental, social and economic sustainability of farms and it proposes the implementation of a fourth dimension, named "governance" within his framework.

The research has started from an indicators' selection. This procedure was based on the literature review. The selection process was carried out through the collection of the indicators detected from currently available methods. Among these, the choice was based on a combination of the best characteristics of simplicity, data requirements and significance for the case study.

The survey on the first set of farms has allowed to an initial selection of the most appropriate indicators of the *IDEA Method* (Vilain et al., 2008), the *RISE Method* (Häni et al., 2003), the *SAFE Method* (Van Cauwenbergh et al., 2007), the *MOTIFS Method* (Meul et al., 2008), the *SOSTARE Model* (Paracchini et al., 2015) and the framework proposed by Thieverge et al. (2014). When no solution were achieved with the literature review, alternative approaches were provided in order to build appropriate indicators able to find a match between the case study and its objectives. With the aim of avoiding redundancy and double-counting, a subset of all collected indicators was selected. The pool of indicators was checked for redundancy and, in the case of multiple choices, the simplest indicator to collect and easiest to understand by the users had priority.

According to the institutional objectives of the case study, the work has then involved the collection of 5 main themes (than called "*components*") for each pillars (see Paragraphs 2.2, 2.3 and 2.4) in which any selected indicator has been placed. This process has led to the establishment of 15 environmental, social and economic components and 5 theoretical governance components.

Some subsequent steps compose the calculation framework starting from *farm characteristics* (*primitive and processed data*) to *sub-indicators*, *indicators* and *components* through a "tree-approach" in order to evaluate each *pillar*. Figure 3.1 provides a scheme of the adopted framework.

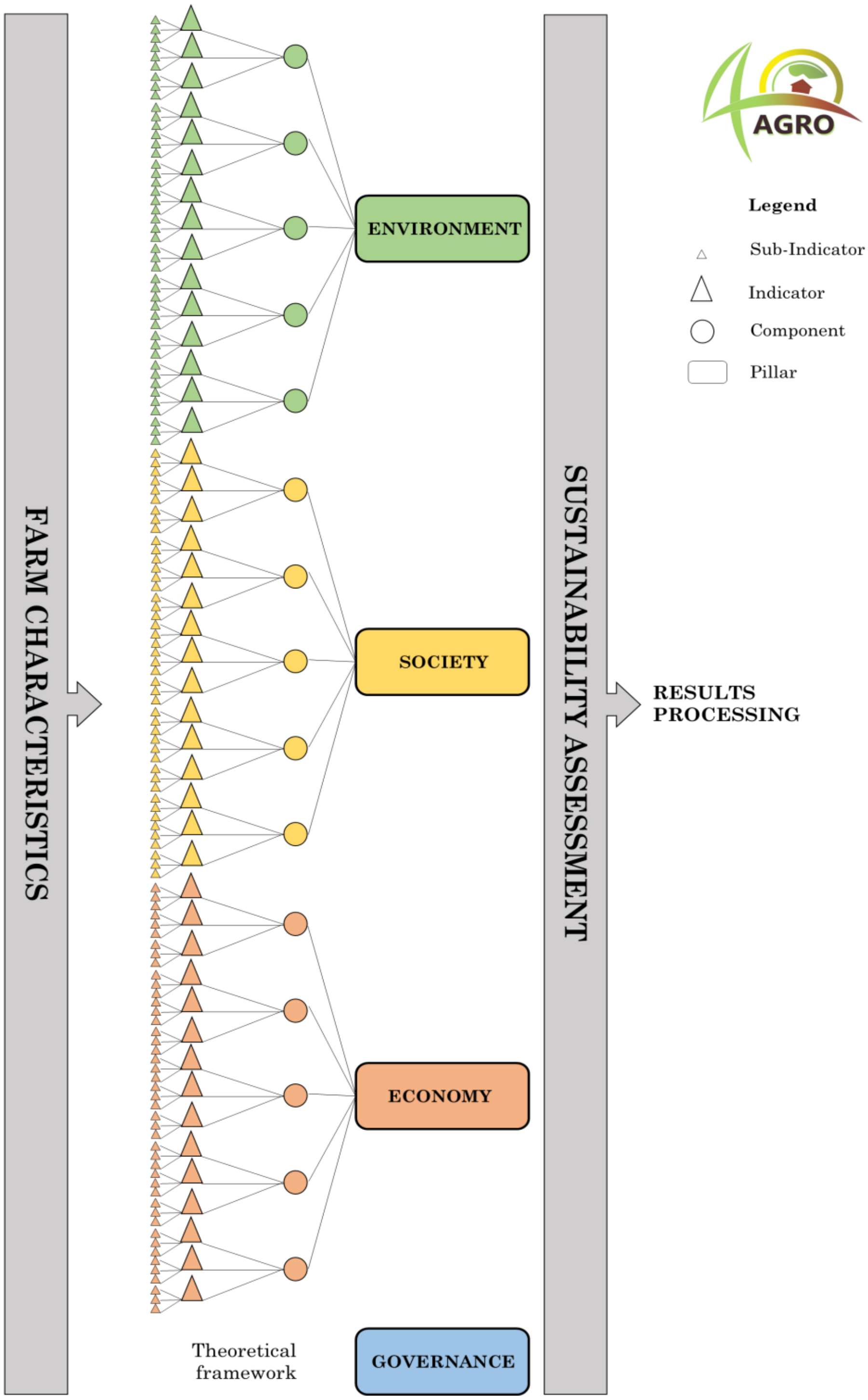



*Figure 3.1: 4Agro, the proposed framework*

The value of each sub-indicator, indicator and component represents easy-to-read scores of the primitive data according to the desirability of the measured performance. Furthermore, each indicator can range from a minimum or a maximum score; while the minimum score is always zero, the maximum scores vary depending on the relevance attributed to the indicator; therefore, more relevant indicators have higher maximum scores. As in many studies, this weighting procedure derived from a subjective evaluation (von Wirén_Lehr, 2001) that assigned the scores in accordance to the relevance attributed by the literature. This process involves the typical risks connected to subjective norms. However, it can be argued that the relative importance given to the various indicators depends on the objectives of the sustainability evaluation and the geographical, technical, economic, political context (Bonneau et al., 2014). In order to reduce this possible source of errors, some studies used the principle of equality among indicators (Van Cauwenbergh et al., 2007; Bonneau et al., 2014), while others chose not to allocate weights to indicators (Häni et al., 2003) that, conceptually it is the same approach. On the contrary, other studies argue that indicators can not be considered equally relevant with reference to sustainability assessment (Vilain et al., 2008, Zahm et al., 2008). The statement that all indicators have the same value would be worse than to attempt allocating weights to them (Thivierge et al., 2014). In this sense, researchers should be aware of the trade-off between the two options and carefully adopt the one that they consider the best in the research context.

The framework is therefore characterized by an aggregative structure aimed at the data reduction starting from the farm characteristics. Figure 3.2 offers a more in-depth schematization of the assessment of each pillar. The process is therefore divided into 4 basic phases:

- *Phase 1*: collection and analysis ($F_{(x)}$ and $G_{(x)}$) of the *farm characteristics* in order to obtain a *raw data set*;
- *Phase 2*: the elaboration of the *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 [variable] score is applied depending on the case;
- *Phase 4*: the sum of two or more indicators provides the value of 5 components for each pillar (thus 15 in total). A minimum

[0] and a maximum [50] score is applied. In turn, the sum of the components leads to the overall value of each pillar of sustainability, which can range from 0 to 250.

It seems appropriate to point out that the creation of an overall sustainability score was not taken into account. According to Viaux (2003) and Zahm et al. (2008), this operation could lead at the providing of incorrect information. Nevertheless, neither the IDEA's key constraints approach was adopted because of the risk of providing insufficient or too simple information of the assessment. The discussion of the results derived from the three pillar and, better, from the relative components, seems to be the best approach in order to provide an exhaustive evaluation of sustainability.

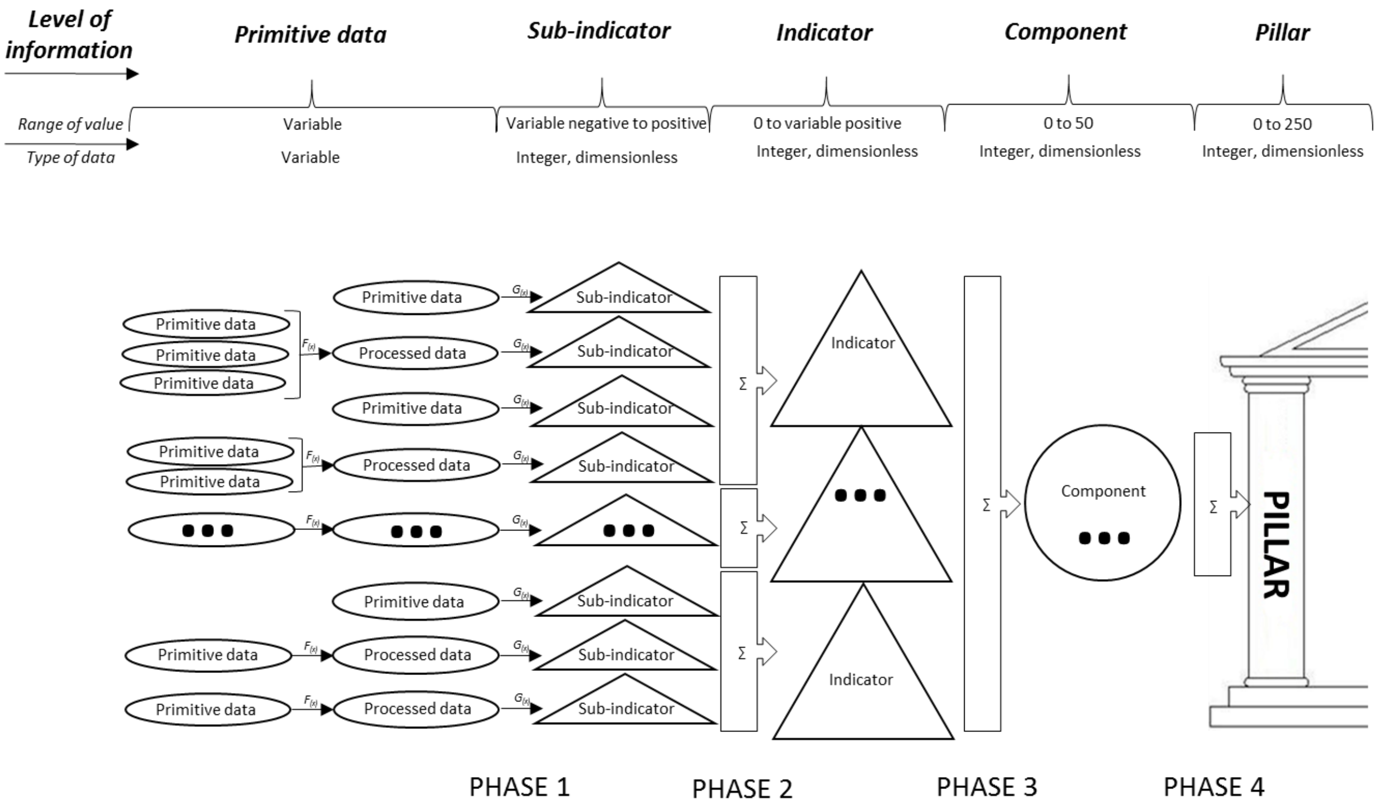



*Figure 3.2: 4Agro, the framework proposed for the sustainability assessment of each pillar*

## 3.2 Case study

The survey was carried out on the region of the *South Milan Agricultural Park* (*Parco Agricolo Sud Milano, PASM*) (Figure 3.3). The *PASM* is a regional metropolitan agricultural park embracing the southern, eastern and western areas of the city of Milan (northern Italy), one of the most intensively agricultural regions in Europe (INEA 2014). The park was created in 1990 to protect and improve natural ecosystems and to safeguard, qualify and promote agricultural activities. It was conceived to provide green areas available to people and to keep farmers in business. This is the prerequisite to avoid the possible abandonment of agricultural lands that could be favoured by the advancement of the city of Milan (Scelsi, 2002). The park covers a plain area of more than 40,000 hectares of lowland, of which 35,000 ha are agricultural; the altitude gradient is about 80-160 m above sea level. The main soil types are loam, sandy-loam, and silt-loam.

Farms are characterized by intensive production systems, a wide range of land areas, livestocks and economic dimensions. The main crops are maize (*Zea mays L.*), rice (*Oryza sativa L.*), permanent meadows, soybean (*Glycine max L.*), winter barley (*Hordeum spp.*), Italian ryegrass (*Lolium multiflorum Lam.*), and winter wheat (*Triticum aestivum L.*) (Castoldi and Bechini, 2010). The main livestocks are cattle, poultry and pigs.

The high population density confers the typical attributes of peri-urban areas, such as fragmentation and high economic value of the land (Gaviglio et al. 2014b).

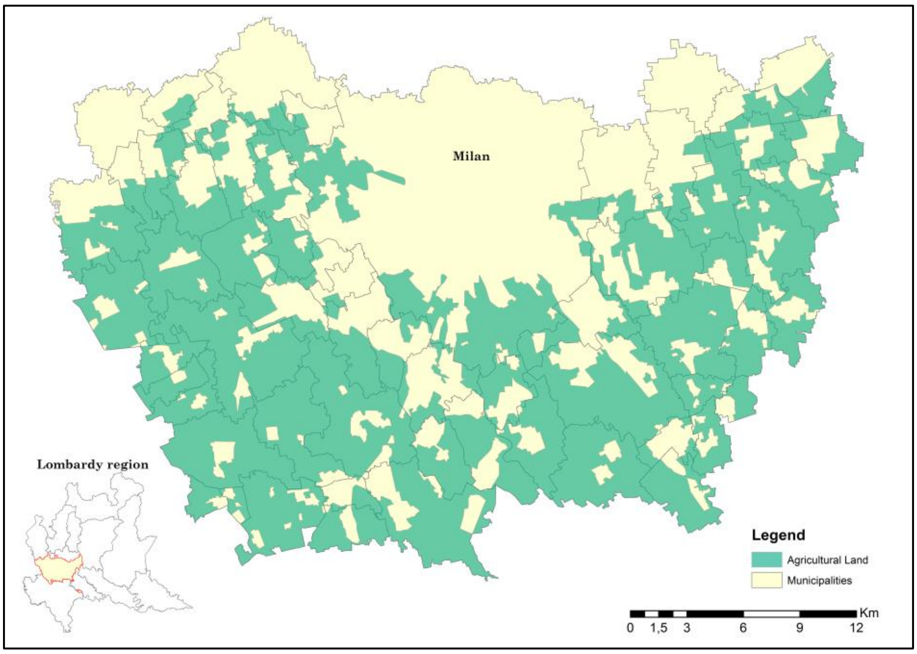



*Figure 3.3: Map of the Parco Agricolo Sud Milano*

## 3.3 Sample selection

The sampling process involved a series of stratifications carried out on the total number of farms belonging to the PASM, conducted on the data available from the *SIARL (Sistema Informativo Agricolo Regione Lombardia)*. At the end of this process, fifty farms with different production systems were selected and analysed during the 2012-2014 period. The *SIARL* database provided rather complete information about surface, livestock, localization and type of production of the farm. The objective was the involvement of the most heterogeneous set of farms, in order to validate the method for a wide range of farm features. On the consequence, the sample was representative of farm types, farm management, geographical location and production systems of the study area. Nevertheless, the selection was also linked to the willingness of farmers to respond to the interviews and to provide some administrative data (Briquel et al. 2001; Viglizzo et al. 2006).

Table 3.1 reports some of the main features of the sampled farms.

*Table 3.1: Characteristics of the sampled farms*

| Farm characteristic | Quantity (N) | Percentage (%) |
|---|---|---|
| **Type of breeding** | | |
| No breeding | 20 | 40.0 |
| Cattle (meat prod.) | 7 | 14.0 |
| Cattle (dairy farms) | 15 | 30.0 |
| Poultry | 4 | 8.0 |
| Pigs | 3 | 6.0 |
| Sheep/Goat | 1 | 2.0 |
| **Land area - Utilized Agricultural Area** | | |
| <50 ha | 23 | 46.0 |
| 50-100 ha | 18 | 36.0 |
| >100 ha | 9 | 18.0 |
| **Multifunctionality** | | |
| Non-multifunctional | 15 | 30.0 |
| Multifunctional | 35 | 70.0 |
| **Type of production** | | |
| Conventional | 41 | 82.0 |
| Organic | 9 | 18.0 |
| **Economic size - Standard Output** | | |
| SO<100 | 28 | 56.0 |
| 100<SO<300 | 14 | 28.0 |
| SO>300 | 8 | 16.0 |
| **Total** | 50 | 100,00 |

Data were collected using:

- interviews to farm personnel. Farms were visited once or, at the best, two times. A questionnaire was filled out in each farm;
- the *SIARL* database;
- data provided by *PASM* documents and previous projects;
- estimations when data were not available through the two other sources.

In the following paragraphs, each pillar is described through an in-depth analysis of the proposed indicators.

## 3.4 Assessment of the environmental sustainability at the farm scale

The analysis of the relevant environmental themes has led to the definition of 18 indicators (Table 3.2).

*Table 3.2 Environmental sustainability indicators and components*

| **Indicator** | | | **Component** | | |
|---|---|---|---|---|---|
| Code | Denomination | Max score | Code | Denomination | Max score |
| 1 | Annual crops diversity | 14 | ENV_1 | Diversity | 50 |
| 2 | Tree crops diversity | 14 | | | |
| 3 | Animal diversity | 14 | | | |
| 4 | Safeguard of the genetic diversity | 8 | | | |
| 5 | Crop rotation | 14 | ENV_2 | Space management | 50 |
| 6 | Plots management | 6 | | | |
| 7 | Ecological buffer zones | 20 | | | |
| 8 | Environmental and landscape safeguard | 4 | | | |
| 9 | Stocking rate | 6 | | | |
| 10 | Fertilization | 20 | ENV_3 | Agricultural practices | 50 |
| 11 | Pesticides | 20 | | | |
| 12 | Veterinary treatments | 3 | | | |
| 13 | Management of the livestock effluents | 7 | | | |
| 14 | Soil management | 20 | ENV_4 | Management of the natural resources | 50 |
| 15 | Water resource management | 20 | | | |
| 16 | Organic matter management | 10 | | | |
| 17 | Energy dependence | 25 | ENV_5 | Energy management | 50 |
| 18 | Renewable energy | 25 | | | |

### 3.4.1 ENV_1 Component: Diversity

The evaluation of the concept of diversity has started to seem fundamental when the agricultural production has become intensive. In particular, the practice of monoculture and specialization in livestock systems has raised relevant questions on the sustainability of the modern farms.

The *ENV_1* component aims at the evaluation of the degree of diversity of cultivations and livestock. In agriculture, the concept of diversity can be defined at three main levels: diversity within individual species, the number of species within a community and the diversity of communities in the local environment (Van Cauwenbergh et al., 2007). The proposed framework has the objective of the evaluation both vegetal and animal diversity, performing an adopted approach of the frameworks proposed by Meul et al. (2008), Vilain et al. (2008) and Thivierge et al. (2014).

It seems appropriate to underline that the concept of *diversity* is deeply different to the one of *biodiversity,* which do not directly involves the number of species of the farm. The proposed indicators have not the purpose of the evaluation of ecological state of the farm, but it offers an exhaustive framework of the diversity level of farm production. These concepts are very different as a farm with a negative output in the diversity indicators of his crops and livestock could be however sustainable in the agro-ecosystem biodiversity. The indirect assessment of biodiversity is performed through the assessment of *ENV_2* component.

Table 3.3 summarizes the *Indicator 1 - Diversity of the annual crops* framework. The evaluation of the number of species and varieties of annual crops (*1_a* and *1_b*) is associated to the presence of leguminous species (*1_c*) that let the achievement of higher scores due to their important positive nitrogen effect, energy and vegetal proteins (Vilain et al., 2008).

The calculation of *Indicator 2 – Perennial crop diversity* (Table 3.4) involves the assessment of tree crops and herbaceous species. The process is similar to the *Indicator 1*. In this case, the framework is structured into three sub-indicators: the number of species (*2_a*) and the respective varieties (*2_b*). The presence of meadows and pastures (*2_c*) attributes additional scores in consideration of their capability to involve different herbaceous species and varieties and to contribute to the fertility improvement of soil, its protections against erosion, the quality of water and landscape (Vilain et al., 2008).

In order to evaluate the diversity of animal species and races, two sub-indicators compose the framework of the *Indicator 3 – Animal diversity* (Table 3.5): sub-indicator *3_a Animal species* considers the number of bred species and *3_b Animal races* considers the number of races for each species.

According to the principle expressed by Meul et al. (2008) and Vilain et al. (2008), the framework of the *Diversity* component attributes equal importance (14 as maximum score each) between the three indicators.

*Table 3.3: Indicator 1 - Annual crop diversity*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| N of annual crop species cultivated | SIARL Database | 1_a | Annual crop species | Counting | 0 to ∞ |
| N of annual crop varieties cultivated | Questionnaire | 1_b | Annual crop varieties | N varieties – N species | 0 to 2 |
| N of leguminous species cultivated | SIARL Database | 1_c | Leguminous species | Counting | 0 to ∞ |
| | | | | **Max score** | 14 |

*Table 3.4: Indicator 2 – Perennial crop diversity*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| N of perennial crop cultivated | SIARL Database | 2_a | Perennial crop species | Counting | 0 to ∞ |
| N of perennial varieties cultivated | Questionnaire | 2_b | Perennial crop varieties | N varieties – N species | 0 to 4 |
| Meadows and pasture surface | SIARL Database | 2_c | Meadows and pastures | Counting | 0 to 3 |
| | | | | **Max score** | **14** |

*Table 3.5: Indicator 3 – Animal diversity*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| N of animal bred species | SIARL Database | 3_a | Animal species | Counting | 0 to ∞ |
| N of animal bred races | Questionnaire | 3_b | Animal races | N races – N species | 0 to ∞ |
| | | | | **Max score** | **14** |

The *Indicator 4 - Safeguard of the genetic diversity* (Table 3.6) is proposed as an additional indicator with the objective of the evaluation of presence of vegetal varieties (*4_a*) or animal races (*4_b*) particularly important because autochthonous, rare or endangered. In this case, the establishment of varieties and races is strictly dependent of the local context. For the case study, documents and publications on the PASM have been used.

*Table 3.6: Indicator 4 – Safeguard of the genetic diversity*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| N of autochthonous and rare vegetal varieties | Local documents | 4_a | Autochthonous and rare varieties | Counting | 0 to ∞ |
| N of autochthonous and rare animal races | Local documents | 4_b | Autochthonous and rare races | Counting | 0 to ∞ |
| | | | | **Max score** | **8** |

### 3.4.2 ENV_2 Component: Space management

The adoption of environmental measures such as crop rotation and landscape improvement contributes to increase the natural value of the farm. The management of farm surface has both environmental and social implications and it has reflections in the biodiversity level, the soil and water management, the use of fertilizers and the quality of the landscape.

The *Indicator 5 - Crop rotation* (Table 3.7) aims at the evaluation of the percentage of farm surface cultivated with the main crop (*5_a*) and the percentage of farm surface on which a crop rotation is applied (*5_c*). In case of the presence of plots where the cultivation is represented by a single and same crop from 3 or more years, a negative score is applied (*5_b*). This indicator is highly correlated to *Indicator 1 – Diversity of the annual crops,* as a negative score in that indicator implies a probable consequent negative result in this indicator. The framework adopts the approaches proposed by Vilain et al. (2008) and Häni et al. (2003) with minor modifications and score's adjustments in order to be more suitable for the case study.

*Table 3.7: Indicator 5 – Crop rotation*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Surface cultivated with the main crop | SIARL Database | 5_a | Main crop surface | % | 0 to 8 |
| Surface cultivated with the same crop from 3 or more years | Questionnaire, SIARL Database | 5_b | Monoculture | % | -1 to 0 |
| Surface on which a crop rotation is applied | SIARL Database | 5_c | Crop rotation | % | 0 to 8 |
| | | | | **Max score** | **14** |

Despite from the economic point of view, the presence of large plots is preferable in order to avoid the waste of productive surface and to favour the farming operation, it is also true that from the environmental side, large plots are more sensible to erosion and the proliferation of parasites (Vilain et al., 2008). In addition, the presence of large plots in a relative small farm surface has negative reflection in the landscape quality and the biodiversity degree (Häni et al., 2003).

In order to assess these characteristics, the *Indicator 6 - Plots management* (Table 3.8) aims at the evaluation of the plot's size (*6_a* and *6_b*). When the entire farm surface is cultivated with grasslands, woodlands or meadows sub-indicator *6_c* attributes the maximum score to the indicator.

*Table 3.8: Indicator 6 – Plots management*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Surface of the biggest plot | Questionnaire | 6_a | Plot's maximum surface | Max | 0 to 6 |
| Average plots surface | Questionnaire | 6_b | Average plots surface | Average | 0 to 2 |
| Presence of meadows and pastures | SIARL Database | 6_c | Meadows and pastures | % | 0 to 6 |
| | | | | **Max score** | **6** |

Agriculture provides multiple ecosystem services and plays a major role in biodiversity conservation and in the maintenance of habitats (Parolo et al., 2011). The presence of landscape elements, such as hedges, rows (*7_a*) resurgences (*7_b*) and water meadow (*7_c*) supports biodiversity, especially in intensively cultivated areas (Carvalheiro et al., 2013). These elements are also supported by the recent CAP reform, which introduces the *EFA (Ecological Focus Area)* among the "*Greening*" requirement. The proposed *Indicator 7 – Ecological buffer zones* (Table 3.9) exploits an adapted framework of the indicators proposed by Vilain et al. (2008) and Paracchini et al. (2015) and it aims at the assessment of the ecological state of the farm, providing information on the active role that farmers play in maintaining biodiversity and guaranteeing the ecosystem service flow to society.

*Table 3.9: Indicator 7 – Ecological buffer zones*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Length of the hedges and the rows | Questionnaire, SIARL Database | 7_a | Hedges and rows | Length / UAA[1] | 0 to 5 |
| Presence of resurgences | Questionnaire | 7_b | Resurgences | Counting | 0 to ∞ |
| Water meadow | Questionnaire | 7_c | Water meadow | Surface | 0 to 5 |
| | | | | **Max score** | **20** |

When the entire or a part of farm surface belongs to areas normed by institutions aimed at the environmental and landscapes safeguard, the presence of constraints forces the farm to follow rules, even if not voluntary, that contribute to the improvement of environmental conditions, according to the objectives of the institution itself. *Indicator 8 - Environmental and landscape safeguard* (Table 3.10) is proposed as an indirect assessment of these features and it evaluates the percentage of farm surface that is included in protected areas. The first sub-indicator (*8_a*) applicated for this case study is referred to the *PASM* that operates through two principal documents: *Norme Tecniche di Attuazione* (*NTA*, Technical Norms) and *Piano di Settore Agricolo* (*PSA*, Agricultural Plan). These documents contain a large number of rules and regulations aimed at: (i) to protect the agricultural activities; (ii) to introduce more sustainable farming practices and agronomic techniques, such as organic farming; (iii) to enhance the landscape, the environment, the cultural and historical heritage, protect the water resources. In order to achieve these objectives, these documents contain environmental and architectural norms that contribute at the improvement of the space management. According to Vilain et al. (2008), sub-indicator *8_b* has been introduced in order to provide additional scores in case of presence of surface that belongs or it is adjacent to the *Natura 2000* areas.

[1] UAA: Utilized Agricultural Area

*Table 3.10: Indicator 8 – Environmental and landscape safeguard*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| UAA belonging to PASM | SIARL Database | 8_a | PASM's surface | % | 0 to 3 |
| UAA belonging to Natura 2000 | SIARL Database | 8_b | Natura 2000 | Surface | 0 to 2 |
| | | | | **Max score** | **4** |

The *stoking rate* of a farm is an indirect quantitative measure of its space valorisation. The autonomy in the forage production is an important indicator in order to the establishment of the sustainability of the livestock. In Europe, a proper balance between the farm surface and the dimension of the livestock is determinant in order to evaluate the compatibly with the *Nitrate Directive*. From the environmental point of view, both the dependence from the outside for the requirement of forage or the need of extra-farm lands for spreading of livestock water-waste are equal considered as unsustainable. The *Indicator 9 – Stocking rate* (Table 3.11) assesses the value of stocking rate of the farm (*8_a*) starting from the establishment of the best value of LUs[2]/UAA stated between 0.5 and 1.4, according to the valuation proposed by Vilain et al. (2008). When value is included into this range, a maximum score is applied. Over and under this range, the indicator attribute decreasing scores.

*Table 3.11: Indicator 9 – Stocking rate*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Stocking rate | SIARL Database | 9_a | Stocking rate | Stocking rate | 0 to 6 |
| | | | | **Max score** | **6** |

### 3.4.3 ENV_3 Component: Agricultural practices

The agricultural practices of a farm have relevant direct and indirect implication in the safeguard of natural capital, especially in intensive areas. In this context, fertilization and the use of agrochemical treatments have a primary role.

[2] LUs: Livestock Units

The evaluation of the fertilizers management through the *Indicator 10 – Fertilization* (Table 3.12) take into account the Nitrogen balance (*10_a*) and the percentage of farm surface used for the cultivation of leguminous species which are able to guarantee an adequate level of nitrogen fixation (*10_b*) (Vilain et al. 2008).

The farm-scale balance for N nutrients (*10_a*) was calculated as a difference between total nutrients imported (organic and inorganic fertilizers, legume fixation, atmospheric deposition), and those exported (cash crops), in accordance to the previous studies proposed by Meul et al. (2008), Vilain et al., (2008) and Paracchini et al. (2015). According to Gourley et al. (2012), the calculated surplus or deficits are presented on a per-ha of UAA basis (kg of nutrient/ha), as follow:

$$(1) \qquad \mathbf{N\ bal} = \frac{\sum(\mathbf{Norg}) + \sum(\mathbf{Ninorg}) + \sum(\mathbf{Natm}) + \sum(\mathbf{Nfix}) - \sum(\mathbf{Ncrop})}{\mathbf{UAA}}$$

The optimum level was set at 30 kg N/ha in accordance to Vilain et al. (2008) which is a less penalizing value compared to what proposed by Thivierge et al. (2014) (10 Kg N/ha).

The *Indicator 11 – Pesticides* (Table 3.13) was created to assess the agrochemical management (herbicides, fungicides and insecticides) through the calculation of the *Pressure Polluting (PP)* that take into account the number of treatments and the surface treated the proportion of UAA calculated as follow (*11_a*):

$$(2) \qquad \mathbf{PP} = \frac{\mathbf{Number\ of\ treatments\ x\ Surface\ treated}}{\mathbf{UAA}}$$

Useful data for this calculation were provided by questionnaires. Because of the detected difficulties in responses during the first interviews, calculation is an adapted framework of the one proposed by Vilain et al. (2008). The index can range from a maximum level of 16 points to a minimum level of -2 points. The use of integrated pest control systems (*11_b*) gives a further contribution to the overall score of the indicator.

*Table 3.12: Indicator 10 - Fertilization*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Norg, Ninorg, Natm, Nfix Ncrop, UAA | Questionnaire, SIARL Database | 10_a | N balance | N balance | -2 to 16 |
| Leguminous species surface | SIARL Database | 10_b | UAA utilized for leguminous species | % | 0 to 5 |
| | | | | **Max score** | **20** |

*Table 3.13: Indicator 11 - Pesticides*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Amount of pesticides used | Questionnaire, SIARL Database | 11_a | Polluting pressure | PP | 0 to 15 |
| Integrated pest treatment | Questionnaire, SIARL Database | 11_b | Integrated pest control systems | % | 0 to 5 |
| | | | | **Max score** | **20** |

In order to provide an evaluation of the use of veterinary substances, the proposed *Indicator 12 – Veterinary treatments* (Table 3.14) aims at the assessment of the use of antibiotics and other supplementary treatments. In this case, for a more relevant evaluation, it would be necessary the consultation of the treatment register, which, however, has been often impossible. Because of that, the proposed framework is based on the evaluation of the frequency of use of these substances. Information were provided by interviews. Because of the indicator's framework, in case of organic or biodynamic production, the maximum score is applied.

*Table 3.14: Indicator 12 – Veterinary treatments*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Use of antibiotics and supplementary treatments | Questionnaire | 12_a | Veterinary treatments | Use frequency | 0 to 3 |
| | | | | **Max score** | **3** |

The *Indicator 13 – Management of the livestock effluents* (Table 3.15) evaluates the type of treatment of effluents with a higher scores for a more environmentally friendly practice.

*Table 3.15: Indicator 13 – Management of the livestock effluents*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Type of livestock treatment | Questionnaire | 13_a | Aerobic treatments | Yes / No | 0 to 2 |
| Type of livestock treatment | Questionnaire | 13_b | Anaerobic treatments | Yes / No | 0 to 2 |
| Type of livestock treatment | Questionnaire | 13_c | Phytoremediation Treatments | Yes / No | 0 to 4 |
| Type of livestock treatment | Questionnaire | 13_d | Composting treatments | Yes / No | 0 to 6 |
| | | | | **Max score** | **7** |

### 3.4.4 ENV_4 Component: Management of natural resources

The evaluation of natural capital of farms involves three main goods: soil, water and air (Serageldin and Steer, 1994). Because of difficulties in the evaluation of the quality of air without direct measurement, in the proposed method, the *ENV_4* component considers only soil and water management through indicators *E_14* and *E_15*. An additional indicator (*E_16*) was added in order to evaluate the management of organic matter.

The soil management strictly depends from the type of farm operation on the farm's surface. Due to the heterogeneity of the production types, the approach adopted by the *Indicator 14 - Soil management indicator* (Table 3.16) doesn't request single information about the operation on individual crop system. It evaluates more general aspects: the percentage of farm surface that is managed through minimum tillage or no tillage operations (*14_a*), the percentage of farm surface covered by vegetation for 11 or more months per year (*14_b*) and the use of methods able to contrast the soil erosion (*14_c*). The framework follows the approaches proposed by Vilain et al. (2008), Thieverge et al. (2014) and Paracchini et al. (2015).

A similar approach is adopted for the assessment of water management (*Indicator 15 – Water resources management,* Table 3.17). The evaluation takes into account the percentage of irrigated surface (*15_a*) of farm and respective methods of irrigation, in order to assess the water use efficiency (Meul et al. 2008): flooding (*15_b*), furrow (*15_c*), sprinkler (*15_d*) and drip or fertigation (*15_e*) irrigation systems are evaluated through a crescent score in relation of the amount of water used by any method.

The *Indicator 16 – Organic matter management* (Vilain et al. 2008) aims at the assessment of the farm's ability to maintain the organic content of the soil through organic fertilization (*16_a* and *16_b*) and the use of compost or similar (*16_c*).

*Table 3.16: Indicator 14 - Soil management*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| UAA treated with minimun tillage or no tillage | Questionnaire | 14_a | Minimun tillage o no tillage | % | 0 to 10 |
| Annual cover index | Questionnaire | 14_b | Annual cover index | % | 0 to 10 |
| Erosion control plans | Questionnaire | 14_c | Erosion control | Multiple choice | 0 to 5 |
| | | | | **Max score** | **20** |

*Table 3.17: Indicator 15 - Water resource management*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Irrigated surface | Questionnaire | 15_a | Irrigated surface | % | 0 to 20 |
| Flooding irrigation | Questionnaire | 15_b | UAA irrigated with flooding systems | % | 0 to 2 |
| Furrow irrigation | Questionnaire | 15_c | UAA irrigated with furrow systems | % | 0 to 5 |
| Sprinkler irrigation | Questionnaire | 15_d | UAA irrigated with sprinkler systems | % | 0 to 10 |
| Drip and fertigation | Questionnaire | 15_e | UAA irrigated with drip or fertigation | % | 0 to 15 |
| | | | | **Max score** | **20** |

*Table 3.18: Indicator 16 - Organic matter management*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Organic fertilization | Questionnaire | 16_a | UAA fertilized Organic fertilization | % | 0 to 5 |
| Exclusive organic fertilization | Questionnaire | 16_b | UAA fertilized exclusively with organic fertilizers | % | 0 to 5 |
| Use of compost and similar | Questionnaire | 16_c | Use of compost and similar | Yes / No | 0 to 2 |
| | | | | **Max score** | **10** |

### 3.4.5 ENV_5 Component: Energy management

The reduction of energy dependency is a primary target for a sustainable agricultural system. As part of a process, this should involve an improvement in time in order to reduce energy consumption and to increase the use of renewable energy, with relevant environmental and economic benefits. Two indicators are proposed.

The consumption of non-renewable energy is evaluated through the *Indicator 17 - Energy dependence* (Table 3.19) which considers the total amount of energy input by converting the fuel, nitrogen, animal feeding, gas and electric fluxes into energy fluxes (Mj) through the use of specific coefficient retrieved from the literature (Meul et al. 2008; Vilain et al., 2008; Paracchini et al. 2015). The calculation of the energy dependency ***EFH (Equivalent Fuel per Hectare)*** derived from the total amount of energy input divided per-ha of UAA (MJ/ha):

$$(3) \qquad \mathbf{EFH} = \frac{\sum(\mathbf{Efuel}) + \sum(\mathbf{Enitrog}) + \sum(\mathbf{Egas}) + \sum(\mathbf{Efeed})}{\mathbf{UAA}}$$

*Table 3.19: Indicator 17 - Energy dependence*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Farm energy consumption | Questionnaire, SIARL Database | 17_a | Energy input | EQF | 0 to 25 |
| | | | | **Max score** | **25** |

The *Indicator 18 – Renewable energy* (Table 3.20) evaluates the use of renewable resources and system for the saving of energy: production of hydraulic energy (*18_a*), wind energy (*18_b*), solar energy (*18_c*), biomass (*18_d*), systems for heat saving (*18_e*), use and/or production of firewood (*18_f*) and use and/or production of bio-fuels (*18_g*).

*Table 3.20: Indicator 18 - Renewable energy*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Production of hydraulic energy | Questionnaire | 18_a | Hydraulic energy | Yes / No | 0 to 4 |
| Production of wind energy | Questionnaire | 18_b | Wind energy | Yes / No | 0 to 4 |
| Production of solar energy | Questionnaire | 18_c | Solar energy | Yes / No | 0 to 4 |
| Production of energy from biomass | Questionnaire | 18_d | Biomass energy | Yes / No | 0 to 4 |
| Systems of heat saving | Questionnaire | 18_e | Heat saving | Yes / No | 0 to 4 |
| Use and/or production of firewood | Questionnaire | 18_g | Firewood | Yes / No | 0 to 2 |
| Use and/or production of bio-fuel | Questionnaire | 18_g | Bio-fuel | Yes / No | 0 to 4 |
| | | | | **Max score** | **25** |

## 3.5 Assessment of the social sustainability at the farm scale

Fifteen indicators (Table 3.21) compose the social pillar framework.

*Table 3.21: Social sustainability indicators and components*

| **Indicator** | | | **Component** | | |
|---|---|---|---|---|---|
| Code | Denomination | Max score | Code | Denomination | Max score |
| 19 | Quality of the products | 20 | SOC_1 | Quality of the products and the territory | 50 |
| 20 | Rural buildings | 12 | | | |
| 21 | Landscape and territory | 18 | | | |
| 22 | Short food supply chain | 30 | SOC_2 | Short food supply chain and related activities | 50 |
| 23 | Related activities | 20 | | | |
| 24 | Work | 25 | SOC_3 | Work | 50 |
| 25 | Sustainability of the employment | 15 | | | |
| 26 | Training | 10 | | | |
| 27 | Livestock management | 25 | SOC_4 | Ethic and human development | 50 |
| 28 | Associations and social implications | 15 | | | |
| 29 | Cooperation | 10 | | | |
| 30 | Waste management | 15 | SOC_5 | Society, culture and ecology | 50 |
| 31 | Accessibility to the farm spaces | 10 | | | |
| 32 | Sustainable use of materials | 15 | | | |
| 33 | Education | 10 | | | |

The method involves the main social themes of the agricultural areas. Nevertheless, few of the topics reported in literature are not treated in order to avoid the use of qualitative indicators of data. In particular, these issues are referred to the food hygiene and safety (Van Cauwenbergh et al., 2007; Rasul and Thapa, 2004; Bonneau et al., 2014; Zahm et al., 2008) and the quality of life (Vilain et al., 2008; Van Cauwenbergh et al., 2007).

### 3.5.1 SOC_1 Component: Quality of the products and the territory

The social inclusion of the rural areas highly depends on the connection between them and the citizenship. One of the most important means is the consumers' perception of the farm's products. Often people assign good environmental standards to the high quality products that contributes to a higher social acceptance of the agriculture and its production systems.

There are wide ranges of categories of consumers, defined as ethical consumers or citizen-consumers, who associate a very high value to the attribute of the quality of the product and the region where they are produced. Among these products, the *Indicator 19 – Quality of the products* (Table 3.22) identified two main categories: the quality certified commodities and food products (*19_a* and *19_b*) and the organic products (*19_c* and *19_d*).

In the first case, the literature review on consumer' perceptions shows some social relation between *PDO* products (*Protected Denomination of Origin*) and the attributes of support in order to sustain regional manufacturers (Van Ittersum et al., 2007; Verbeke et al., 2012) and to contribute to the survival of the social identity of the region (Vilain et al., 2008). Thus, nowadays these recent purchasing motivations are assigned a comparable importance with the typical attributes such as the high standards (Van Ittersum et al., 2007), the tradition (Verlegh and Steenkamp, 1999; Dimara and Skuras, 2003), the pleasant taste (Platania and Privitera, 2006; Vanhonacker et al., 2010) and food safety (Dimara and Skuras, 2003).

Regarding organic food consumption, many researches stated the importance of the socio-economics traits of consumers (Hamm and Gronefeld, 2004; Falguera et al., 2012), in particular the tradition (Chinnici et al., 2002) and the animal welfare (Magnusson et al., 2003; Makatouni, 2002). In this case too, these attributes seem to have a primary relevance, besides to those historically associated with organic consumption: first of all the environmentally-friendly behaviour and also, as stated by some recent studies, the importance of the intrinsic attributes of the products (Gaviglio et al., 2015a), such as the healthiness (Pieniak et al., 2010), the high-quality (Chinnici et al., 2002) and the taste (Fotopoulos et al., 2002; Zanoli and Naspetti, 2002; Kihlberg and Risvik, 2007).

While the establishment of the organic and labelled products is easy because of the certification, there are a wide range of attempts to define the local products (Hand and Martinez, 2010). Because of the difficulties in defining the standard of quality of products without certifications, this component only considers labelled products. The evaluation of local and typical products is treated by the *SOC_2* component, without taking into account the attribute of their quality.

*Table 3.22: Indicator 19 - Quality of the products*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| N of products involved in quality certified products | Questionnaire | 19_a | Quality certified commodities | Counting | 0 to ∞ |
| N of quality certified products | Questionnaire | 19_b | Quality certified food products | Counting | 0 to ∞ |
| N of vegetal organic products | Questionnaire | 19_c | Vegetal organic production | Counting | 0 to ∞ |
| N of animal organic products | Questionnaire | 19_d | Animal organic production | Counting | 0 to ∞ |
| | | | | **Max score** | **20** |

Finally, the component evaluates the issues not closely linked to the products, such as the functional and aesthetic roles of rural buildings *(Indicator 20,* Table 3.23) and farm landscape *(Indicator 21,* Table 3.24). These are important features that characterizes the architecture (Meul et al., 2008) and they represent positive or negative externalities in the social acceptance of the rural areas (Van Cauwenbergh et al., 2007).

*Table 3.23: Indicator 20 - Rural buildings*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Aesthetics care of rural buildings | Questionnaire | 20_a | Aesthetics of rural buildings | Multiple choice | 0 to 4 |
| Maintenance of the original use of the rural buildings | Questionnaire | 20_b | Maintenance of the original use of the rural buildings | Multiple choice | 0 to 4 |
| N of buildings built or renovate using "green tequiniches" | Questionnaire | 20_c | Green building techniques | Counting | 0 to ∞ |
| | | | | **Max score** | **12** |

*Table 3.24: Indicator 21 - Landscape and territory*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Maintenance of the farm green spaces | Questionnaire | 21_a | Green maintenance | Multiple choice | 0 to 4 |
| Presence of hedges, rows and wooded bands | Questionnaire | 21_b | Hedges, rows and wooded bands | Multiple choice | 0 to 4 |
| Maintenance of the roads and paths | Questionnaire | 21_c | Maintenance of the roads and paths | Multiple choice | 0 to 4 |
| N of crop species / UAA | SIARL Database | 21_d | Crop diversification | % | 0 to 6 |
| | | | | **Max score** | **18** |

### 3.5.2 SOC_2 Component: Short food supply chain and related activities

Among the most important motivations in buying local products, the literature found some social attributes such as the tradition (Bessiére, 1998), the supporting local economies and trust in producers (Lockie, 2009; Seyfang, 2006). These are indicated by consumers as relevant means able to connect the citizenship with the countryside.

Selling products through short chain systems involves different types of means, such as the direct sales (*22_a, 22_c* and *22_d)*, the online sales *(22_b),* the ethical purchasing groups *(22_e)*, the farmers' markets *(22_f)*, the restaurants and shops *(22_g)* and canteens *(22_h).* The direct sales formula is mainly dedicated to the local products and it creates a close relationship between producers and consumers which cannot be explained just within an economic rationality (Gaviglio et al., 2015b). The framework of the *Indicator 22* is reported in Table 3.25.

*Table 3.25: Indicator 22 - Short food supply chain*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Selling through direct sales | Questionnaire | 22_a | Direct sales | Yes/No | 0 to 3 |
| Selling through online website | Questionnaire | 22_b | Online sales | Yes/No | 0 to 1 |
| Income from short chain channels | Questionnaire | 22_c | Direct sales relevance | % | 0 to 20 |
| N of product sold through direct sale channels | Questionnaire | 22_d | Product sold through direct sales | Counting | 0 to ∞ |
| Sales through ethical purchasing groups (EPG) | Questionnaire | 22_e | Sales through (EPG) | Multiple choice | 0 to 3 |
| Sales through farmers' markets | Questionnaire | 22_f | Sales through farmers' markets | Multiple choice | 0 to 2 |
| Sales to restaurant and shops | Questionnaire | 22_g | Sales to restaurant and shops | Multiple choice | 0 to 2 |
| Sales to canteens | Questionnaire | 22_h | Sales to dining halls | Multiple choice | 0 to 3 |
| | | | | **Max score** | **30** |

The implications on other activities besides the agricultural production (*Indicator 23*, Table 3.26), such as the maintenance and the management of the public spaces and resources (*23_a*), the related activities like agritourism, restaurants, bed & breakfasts (*23_b*) and educational farms (*23_c* and *23_d*) are other important means of linking the town and the countryside (Vilain et al., 2008). Citizens often use these systems to get to know the rural world and to learn about production processes and agro-food systems (Santini and Paloma, 2013). This is of primary importance in peri-urban areas, where the short spatial distance between the countryside and the town is often a big distance in culture, economy and lifestyle.

*Table 3.26: Indicator 23 - Related activities*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Social services | Questionnaire | 23_a | Social services | Yes/No | 0 to 2 |
| Type of related activities | Questionnaire | 23_b | Type of related activities | Multiple choice | 0 to 10 |
| Educational farm, teaching | Questionnaire | 23_c | Educational farm | Multiple choice | 0 to 5 |
| Presence of other social activities | Questionnaire | 23_d | Social activities | Yes / No | 0 to 5 |
| | | | | **Max score** | **20** |

### 3.5.3 SOC_3 Component: Work

Employment in the agriculture sector has fallen considerably in the last decades. On the consequence, the maintenance of a sustainable level of employment (*Indicator 24,* Table 3.27) is relevant for the social and economic development (*Indicator 25,* Table 3.28) of the area (Häni et al., 2003; Meul et al., 2008; Vilain et al., 2008; Gómez-Limón and Fernandez, 2010; Reig-Martinez et al., 2011; Bonneau et al., 2014).

*Table 3.27: Indicator 24 - Work*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Annual amount of work | SIARL Database | 24_a | Annual Work Unit (AWU) | Ha / hours | 0 to 8 |
| N of new employments (in the last 5 years) | Questionnaire | 24_b | New employments | Counting | 0 to ∞ |
| N of farm products processing | Questionnaire | 24_c | Farm products processing | Counting | 0 to ∞ |
| | | | | **Max score** | **25** |

*Table 3.28: Indicator 25 - Sustainability of the employment*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| N of workers who resided in the farm buildings | Questionnaire | 25_a | Workers who resides in the farm buildings | Counting | 0 to 2 |
| Number of local workers | Questionnaire | 25_b | Local workers | % | 0 to 1 |
| Number of female workers | Questionnaire | 25_c | Female workers | % | 0 to 4 |
| Age of the entrepreneur | Questionnaire | 25_d | Youth entrepreneurship | Yes / No | 0 to 4 |
| Youth workers | Questionnaire | 25_e | Youth employment | % | 0 to 4 |
| | | | | **Max score** | **15** |

In this context, training (*Indicator 26,* Table 3.29) is a key aspect for the growth of the agricultural sector (Vilain et al., 2008) by which farms play a leading role in development and innovation because of the requirement for high-profile skilled jobs involved in related activities, research and breeding.

*Table 3.29: Indicator 26 - Training*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Training courses for workers formation | Questionnaire | 26_a | Training courses | Multiple choice | 0 to ∞ |
| Presence of trainees from schools and universities | Questionnaire | 26_b | Trainees | Yes / No | 0 to 2 |
| Training activities unfold in farm | Questionnaire | 26_c | Training activities unfold in the farm | Yes / No | 0 to 2 |
| Employment of disadvantaged people among the workers | Questionnaire | 26_d | Disadvantaged people hired | Yes / No | 0 to 5 |
| | | | | **Max score** | **10** |

### 3.5.4 SOC_4 Component: Ethic and human development

The human and ethical developments of agriculture involve multiple issues. Among these, animal welfare is today a primary requirement of the society (Fortun-Lamothe et al., 2009; Broom, 2010). Livestock management involves animal health and the farm's ability to implement innovations in the agricultural sector. This is a very complex issue and the use of a single approach able to evaluate different types of livestock is difficult. Therefore, the indicator *Indicator 27* (Table 3.30) is based on the diversification of the most common species of animals (cattle, pigs, poultry, sheep/goats) bred in the area. In this way, only the management of the most important livestock of the farm was evaluated (through the calculation of the LSU, "livestock units"). The information were provided by questionnaire and the method of calculation was based on multiple choice.

*Table 3.30: Indicator 27 – Livestock management*

**27_a Number of species in the livestock** (0 to ∞)

Choosing of the most important livestock of the farm

| **Cattle** | **Pigs** | **Poultry** | **Sheep and goats** |
|---|---|---|---|
| 27_b1 Type of stable | 27_c1 Type of flooring | 27_d1 Type of stable | 27_e1 Outdoor spaces and pasturage |
| 27_b2 Management by physiological phases | 27_c2 Systems of ventilation | 27_d2 Systems of ventilation | 27_e2 Quality/quantity of the feed |
| 27_b3 Systems of ventilation | 27_c3 Handling systems of animals | 27_d3 Presence of openings and/or windows | 27_e3 Attendance at birth |
| 27_b4 Quality/quantity control of the feed | 27_c4 Presence of materials of environmental enrichment | 27_d4 Quality/quantity control of the feed | 27_e4 Systems of cleaning |
| 27_b5 Attendance at birth | | | |
| 27_b6 Systems of cleaning | | | |
| | | **Max score** | **25** |

Cooperation and association are relevant means of innovation of agricultural systems (Vilain et al., 2008) and they are important indicators of the human development in rural areas. Among these factors, the social dynamism and vitality of an area heavily depend on membership in associations (*28_a* and *28_b*), consortia (*28_c*) and cooperation with other farms in the surrounding area in the direct sales (*29_a* and *29_b*), agritourism activities (*29_c*), the production structures (*29_d*) and the workforce (*29_e*) (Table 3.31 and Table 3.32).

*Table 3.31: Indicator 28 - Associations and social implications*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Participation in associations | Questionnaire | 28_a | Association | Yes / No | 0 to 5 |
| Position of responsibility in associations | Questionnaire | 28_b | Responsibility in the associations | Yes / No | 0 to 5 |
| Participation in consortium | Questionnaire | 28_c | Consortium | Yes / No | 0 to 5 |
| The entrepreneur resides in farm | Questionnaire | 28_d | Residence of the entrepreneur in farm | Yes / No | 0 to 2 |
| | | | | **Max score** | **15** |

*Table 3.32: Indicator 29 - Cooperation*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Direct sales managed in cooperation | Questionnaire | 29_a | Direct sales managed in cooperation | Yes / No | 0 to 2 |
| Selling of other farm's products | Questionnaire | 29_b | Selling of other farm's products | Yes / No | 0 to 2 |
| Agri-tourism managed in cooperation | Questionnaire | 29_c | Agri-tourism managed in cooperation | Yes / No | 0 to 2 |
| Farm structures and/or machineries managed in cooperation | Questionnaire | 29_d | Farm structures and machineries managed in cooperation | Yes / No | 0 to 2 |
| Workforce managed in cooperation | Questionnaire | 29_e | Workers managed in cooperation | Yes / No | 0 to 2 |
| | | | | **Max score** | **10** |

### 3.5.5 SOC_5 Component: Society, culture and ecology

The inclusion of rural areas involves the recognition of the ecological, cultural and social effort of farms in their production process. In this sense, the component takes into account four main aspects.

A proper waste management through recycling processes (*30_a)* and the use of recycled materials (*30_b*, *30_c* and *30_d*) has a great environmental importance but it also involves the social acceptance of the agriculture systems (Table 3.33). The farm's open spaces (*31_a* and *31_b*) have important recreational functions useful for the population of a rural area (Table 3.34).

*Table 3.33: Indicator 30 - Waste management*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Separate waste management | Questionnaire | 30_a | Waste management | Yes / No | 0 to 4 |
| Use of recyclable materials | Questionnaire | 30_b | Recyclable materials for the farm activities | Yes / No | 0 to 4 |
| Use of compost | Questionnaire | 30_c | Use of compost | Yes / No | 0 to 3 |
| Mulching | Questionnaire | 30_d | Mulching | Yes / No | 0 to 4 |
| | | | | **Max score** | **15** |

*Table 3.34: Indicator 31- Accessibility to the farm spaces*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Presence of public farm spaces | Questionnaire | 31_a | Public farm spaces | Yes / No | 0 to 5 |
| Presence of recreational farm spaces | Questionnaire | 31_b | Recreational farm spaces | Yes / No | 0 to 5 |
| | | | | **Max score** | **10** |

Moreover, a proper landscape management can be a relevant source of income for the multifunctional farm's activities (Vilain et al., 2008). The agricultural production systems involve the use of materials, such as feed (*32_a*), fertilizers (*32_b*), water (*32_c*) and seeds (*32_e*) that characterizes the sustainability of the farm management (Vilain et al., 2008). A high dependence from the outset, even the buying of animals (*32_c*), often causes a reduction of autonomy in making production, marketing and management decisions. It also alters the resilience of the system and the ability to adapt to economic, environmental and social changes (Table 3.35).

*Table 3.35: Indicator 32 - Sustainable use of materials*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Self produced feed | Questionnaire | 32_a | Self-produced feed | % | 0 to 5 |
| Self-produced fertilizer | Questionnaire | 32_b | Self-produced fertilizers | % of Nitrogen | -1 to 5 |
| Amount of livestock comeback | Questionnaire | 32_c | Livestock comeback | Multiple choice | 0 to 4 |
| Use of methods for the water saving | Questionnaire | 32_d | Saving water | Yes / No | 0 to 2 |
| Self-produced seeds and plants | Questionnaire | 32_e | Self-produced seeds and plants | Yes / No | 0 to 2 |
| | | | | **Max score** | **15** |

The educational level (*Indicator 33,* Table 3.36) of the farm personnel is important for the cultural and social growth of agricultural areas (Van Cauwenbergh et al., 2007). As found by Elfkih et al. (2012), there is a probable positive effect of educational level on achievement of overall sustainability achievement. The education of the workforce and the entrepreneur is also able to encourage on openness to new knowledge and the innovation in agriculture.

*Table 3.36: Indicator 33 - Education*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Schooling level of the farm workers | Questionnaire | 33_a | Schooling level of the farm workers | Index | 0-10 |
| | | | | **Max score** | **10** |

## 3.6 Assessment of the economic sustainability at the farm scale

The analysis of the relevant economic themes has led to the definition of 9 indicators (Table 3.37).

*Table 3.37: Economic sustainability indicators and components*

| **Indicator** | | | **Component** | | |
|---|---|---|---|---|---|
| Code | Denomination | Max score | Code | Denomination | Max score |
| 34 | Value of production | 30 | ECO_1 | Economic viability | 50 |
| 35 | Value added | 20 | | | |
| 36 | Farm ability to generate income | 25 | ECO_2 | Transmissibility | 50 |
| 37 | Income per family worker | 25 | | | |
| 38 | CAP Independence | 25 | ECO_3 | Independence | 50 |
| 39 | Autonomy | 25 | | | |
| 40 | Diversification of the production | 30 | ECO_4 | Diversification | 50 |
| 41 | Farm business diversification | 20 | | | |
| 42 | Multifunctionality | 50 | ECO_5 | Multifunctionality | 50 |

### 3.6.1 ECO_1 Component: Economic viability

The Economic Viability is one of the determinants of the economic performance of a farm.

Two main parameters have been considered: the Value of Production (VP) and the Value Added (VA).

The VP is the value of goods and services produced by a farm during a year. It is particularly interesting when evaluated per unit of input. According to Paracchini et al. (2015), since in the present survey different types of production have been taken into account, the VP has been measured in relation to both the UAA (34_a) and the AWU[3] (34_b):

$$(3) \quad \mathbf{34\_a} = \frac{\mathbf{VP}}{\mathbf{UAA}} \qquad\qquad (4) \quad \mathbf{34\_b} = \frac{\mathbf{VP}}{\mathbf{AWU}}$$

The VA represents the increase in value generated from the production process to the value of intermediate consumption that includes raw materials (RM), direct energy (EN) and services (SC). The VA is calculated as follows:

$$(5) \quad \mathbf{VA} = \mathbf{VOP} - (\mathbf{RM} + \mathbf{EN} + \mathbf{SC})$$

According to Meul et al. (2008), in the *Indicator 35* (Table 3.39) the VA was also related to the two major farm inputs, UAA (35_b) and AWU (35_b):

$$(6) \quad \mathbf{35\_}\boldsymbol{a} = \frac{\mathbf{VA}}{\mathbf{UAA}} \qquad\qquad (7) \quad \mathbf{35\_}\boldsymbol{b} = \frac{\mathbf{VA}}{\mathbf{AWU}}$$

Table 3.39 and Table 3.38 summarizes, respectively, the *Indicator 34 – Value of production* and the *Indicator 35 – Value added.*

*Table 3.38: Indicator 34 - Value of production*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Value of production per hectare of UAA | SIARL Database / Questionnaire | 34_a | Value of production per hectare UAA | 34_a | 0 to 15 |
| Value of production per AWU | SIARL Database / Questionnaire | 34_b | Value of production per AWU | 34_b | 0 to 15 |
| | | | | **Max score** | **30** |

[3] AWU: Annual Work Units

*Table 3.39: Indicator 35 – Value added*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Value added per hectare of UAA | SIARL Database / Questionnaire | 35_a | Value added per hectare of UAA | 35_a | 0 to 15 |
| Value added per AWU | SIARL Database / Questionnaire | 35_b | Value added per AWU | 35_b | 0 to 15 |
| | | | | **Max score** | **20** |

### 3.6.2 ECO_2 Component: Transmissibility

Since the maximisation of household income is one of the main goals of farms, in the study of farm profitability, the calculation of the EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortisation) was selected in order to quantify the farm household income. The value is obtained by subtracting the cost of employees from the VA. According to Paracchini et al. (2015), the EBITDA doesn't include the cost of capital depreciation, as it is difficult to measure. The *Indicator 36* (Table 3.40) represents the amount of the household income through the ratio between EBITDA and VP.

$$(8) \qquad 36\_a = \frac{\textbf{EBITDA}}{\textbf{VP}} X100$$

*Table 3.40: Indicator 36 – Farm ability to generate income*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Farm household income | SIARL Database / Questionnaire | 36_a | Farm household income | 36_a | 0 to 25 |
| | | | | **Max score** | **25** |

The framework of the *Indicator 37* (Table 3.41) is based on the ratio between the sum of EBITDA and the income derived from public subsidies (CAP) and family working unit (FWU) represents the income per family worker codified (Vilain et al., 2008):

$$(9) \qquad 37\_a = \frac{\textbf{EBITDA + CAP}}{\textbf{FWU}} \textbf{X100}$$

*Table 3.41: Indicator 37 – Income per family worker*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Income per family worker | SIARL Database / Questionnaire | 37_a | Income per family worker | 37_a | 0 to 25 |
| | | | | **Max score** | **25** |

### 3.6.3 ECO_3 Component: Independence

The independence component provides information on financial autonomy and sensitivity to subsidies and allowances.

The issued related to the dependency of farm income on public support is crucial. According to Van Cauwenbergh et al. (2007), Vilain (2008) and Paracchini et al. (2015), the extent of the farm household income that depends on EU public subsidies and how much is derived from the market needs to be taken into account in the analysis. A specific indicator (*38*, Table 3.42) was calculated to evaluate the incidence of the CAP:

$$(10) \qquad \mathbf{38\_}\boldsymbol{a} = \frac{\mathbf{CAP}}{\mathbf{EBITDA + CAP}}$$

*Table 3.42: Indicator 38 - CAP Independence*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| CAP incidence | SIARL Database / Questionnaire | 38_a | CAP incidence | 38_a | 0 to 25 |
| | | | | **Max score** | **25** |

According to Vilain et al. (2008), the financial autonomy of a farm has important reflection both to the economy and the social state of the rural area. It affects the farm's availability to introduce innovations and create new workplaces. The *Indicator 39 – Autonomy* aims at the assessment of the financial autonomy of a farm accounting the total amount of loans and financing in general, in relation to the value of the total asset.

*Table 3.43: Indicator 39 - Autonomy*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Financial autonomy | SIARL Database / Questionnaire | 39_a | Financial autonomy | Index | 0 to 25 |
| | | | | **Max score** | **25** |

### 3.6.4 ECO_4 Component: Diversification

The *Diversification* component is based on the assumption that diversification in economic activity is economically more sustainable than specialization (Elfkih et al., 2012) and a higher rate of specialization implies a greater risk from the economic point of view (Vilain et al., 2008).

The *Indicator 40* (Table 3.44) evaluates the number of products (*40_a*), services (*40_b*) and the spread among them (*40_c*).

*Table 3.44: Indicator 40 – Diversification of the production*

| **Farm characteristic** | **Data source** | **Code** | **Sub-indicator** | **Method of calculation** | **Range score** |
|---|---|---|---|---|---|
| Number of farm products | Questionnaire | 40_a | Number of farm products | Counting | 0 to ∞ |
| Number of farm services | Questionnaire | 40_b | Number of farm services | Counting | 0 to ∞ |
| Products and services spread index | Questionnaire | 40_c | Products and services spread index | Index | 0 to 10 |
| | | | | **Max score** | **30** |

The *Indicator 41* (Table 3.45) assesses the business diversification of the farm, taking into account the economic weight of the main clients (41_a) and the one related to the short food supply chain (*41_b*).

*Table 3.45: Indicator 41 - Farm business diversification*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Economic weight of the main client | Questionnaire | 41_a | Economic weight of the main client | % | 0 to 10 |
| Economic weight of the short food supply chain | Questionnaire | 41_b | Economic weight of the short food supply chain | % | 0 to 10 |
| | | | | **Max score** | **20** |

### 3.6.5 ECO_5 Component: Multifunctionality

From the economic point of view, the concept of farm multifunctionality is deeply different to the one associated to the farm's ability to provide social and ecological benefit to the community; goods that are difficult to monetize because of their heterogeneity and complexity. On the contrary, the literature on the multifunctional feature of a farm focuses mainly on the determinants of the adoption of diversification and related activities (Jongeneel et al., 2008; Mann, 2009). Meert et al. (2005) underlined different diversification pathways in the context of the agricultural production or with the introduction of new non-agricultural products and services. The amount of farm's income derived from non-agricultural activities (but however related to it) such as agriturism, direct sales, school farm require skills and abilities able to contribute to the diversification of production and a greater economic security and resilience of the farm.

*Table 3.46: Indicator 40 - Multifunctionality*

| Farm characteristic | Data source | Code | Sub-indicator | Method of calculation | Range score |
|---|---|---|---|---|---|
| Level of multifunctionality | Questionnaire | 42_a | Multifunctionality index | Index | 0 to 50 |
| | | | | **Max score** | **50** |

## 3.7 A proposal framework for the governance assessment

As outlined in the Paragraph 2.6, among the scientific community, the conceptual framework based on the traditional three pillars has been recently integrated with a new approach based on four main themes that adds the role of the institutions to the environmental, social and economic themes.

A theoretical conceptualization of this new pillar is well-established through the SAFA (Sustainability Assessment of Food and Agriculture Systems) framework (FAO, 2014) (Figure 3.4). The study offers an in-depth analysis of the main themes related to the so-called Good Corporate Governance (GCG) with the aim of taking into account all affected stakeholders. This includes *Corporate ethics*, *Accountability*, *Participation*, *Rule of law* and *Holistic management*. The concept is based on the statement that if the good governance is not seriously considered, the environmental, social and economic sustainability will remain a mirage.

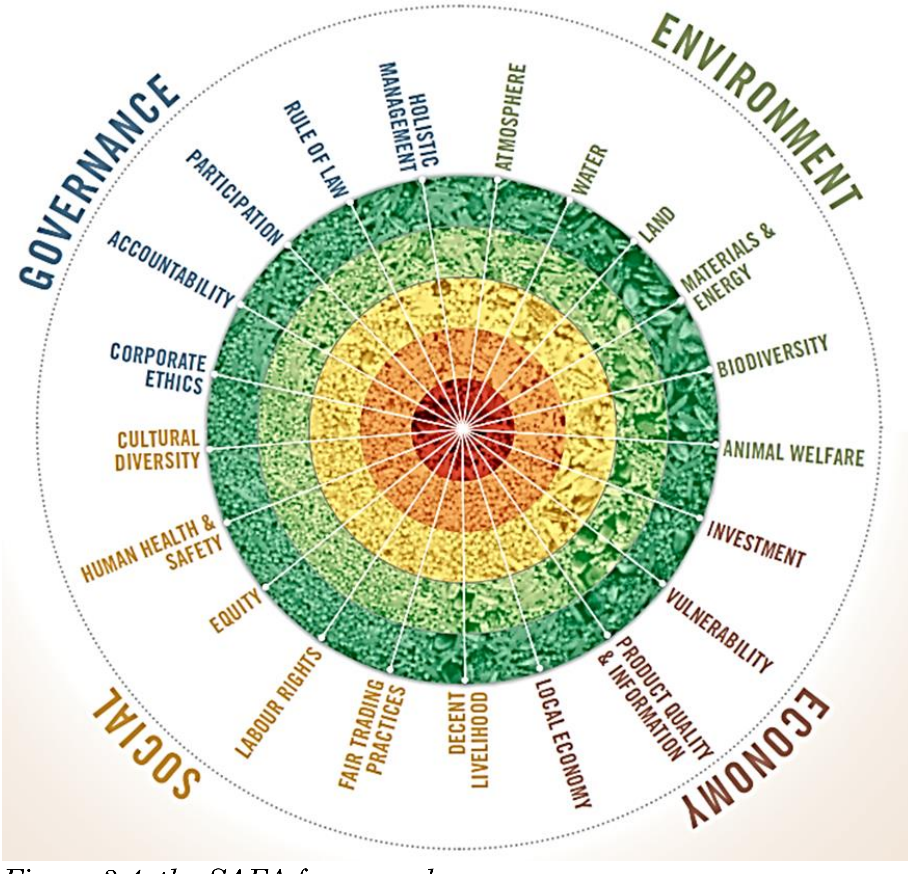



*Figure 3.4: the SAFA framework*

Following these concepts, at the farm level, the objective of the evaluation of the environmental, social and economic sustainability has an absolute significance but it also has a dynamic objective which aims to assess the real capacity of local and European policies to bring farms to improve their levels over time. It seems obvious that the assessment of the achieved levels during time becomes more interesting in the presence of projects and activities that are undertaken at the institutional level. This assessment is even more interesting whether the policies have led to an improvement of less efficient farms. It involves local projects (which depend on the local context) and European polices, with particularly reference to the second pillar of the CAP. In the past, the RPD has often proved useful for farms that were already very good in their environmental and structural characteristics. Therefore, they often could easily access to funds (especially agri-environmental) through easy and inexpensive adaptations. This has often favoured their competitiveness, but it has had a partial environmental impact. Conversely, less sustainable farms have often neglected the access to these measures because considered too far to reach for their standards. In this sense, the evaluation of the compatibility and the willingness to access to these governance projects, both local and European, could offer a useful indication to policy-makers.

In this study, a proposal framework (Table 3.47) has been suggested in order to evaluate the agricultural governance through the evaluation of the aspects mentioned above.

*Table 3.47: Proposed criteria for assessing the governance dimension of sustainability at the farm scale*

| **Component** | **Variables for analysis** |
|---|---|
| Partecipation to local initiatives | Local marks, local projects |
| Communication and visibility | Partecipation on websites, social networks, magazines |
| RDP: Compatibility to environmental measures | Willingness and eligibility for access to funds |
| RDP: Farm's compatibility to social measures | Willingness and eligibility for access to funds |
| RDP: Farm's compatibility to economic measures | Willingness and eligibility for access to funds |

## 3.8 Farm ranking approaches

The method provides the scores of each sub-indicator, indicator and component that contribute to the overall score of the three pillars. In relation to the objective of the research, the method allows the use of different solutions of data processing.

The framework is able to provide easy-to-read results and information at different scales of interpretation. The *farm ranking approaches* are instruments by which compare farm's performances in order to evaluate individual farms or homogeneous groups of them. These approaches have been used by numerous studies (e.g. Vilain et al., 2008; Parrachini et al., 2015; Häni et al., 2003) in order to provide information at multiple levels.

Results could be useful to identify agricultural sustainable practices and farm's features that mostly influence sustainability, such as the type of production, the land area and the multifunctional activities. The framework is also able to detect individual and detailed aspects of sustainability, as well as a high variability of the same aspects aggregated together to a more comprehensive vision of the evaluation.

## 3.9 Statistical analysis

A statistical analysis was carried out with the main objective of analysing the relationships among variables and identifying which of those scores are the most significant to account for the observed variability among farms, similarities and differences among farming systems and associations among indicators. A second goal involved a reflection about the possibility of improvement of data requirement. In fact, as other sustainability tools, *4Agro* needs for a large number of raw data (farm characteristics). On the consequence, their collection was time-consuming and costly. According to the procedure developed by Bonneau et al. (2014), a data reduction approach was applied in order to reach a simplified framework.

All statistical analyses were carried out in IBM SPSS, version 21.

The statistical procedure has followed this primary steps:

- a matrix of correlation was calculated in order to establish relation among scores of indicators and pillars. These correlations were calculated using the *Pearson correlation*;

- a *PCA (Principal Component Analysis)* was performed within the scores of the indicators of each pillar (as variables) of the 50 sampled farms (as individuals), ignoring the farm' category (Jolliffe, 2002). As a results three *PCA* were performed;
- three *Cluster analysis* (one for each pillar) were carried out on the basis of the scores of the *PCA analysis*. The aim of *Cluster analysis* was to group a set of objects (the farms in this study). The analysis offered useful information in order to establish which farms of the same group were more similar to each other than to those in other groups. The analysis was carried out using the "medium bond among groups" as grouping method. The outputs of the analysis were facilitated by the observation of the relative dendrogram;
- on the basis of the *PCA* and *Cluster analysis* results, it was carried out a discussion about farming systems, correlations and approaches in order to consider the opportunity of reducing the number of useful indicators;
- a second series of *PCA* and *Cluster analysis* was performed on a reduced number of indicators in order to evaluate the usefulness of a smaller data set (Bonneau et al., 2015a).

## 3.10 Relevant challenging issues involved in the assessment process

Considering the difficulties in performing the evaluation of very different types of farms in the area through a unique approach (Paragraph 3.1), it seems necessary to specify some critical aspects of the approach. In particular, there was a relevant difficulty in the objective of the evaluation of livestock farms and no-livestock farms with the same approach. Among the three pillars, the economic one was not affected in any way by this issue: the economic indexes are valid in the same way for all types of farms. On the contrary, the environmental and the social pillars have shown some critical.

In the first case, the indicators *9 – Stocking rate*, *12 – Veterinary treatments* and *13 – Management of the livestock effluents* are directly related to presence of a livestock and their evaluation is unnecessary, penalizing or misleading in case of no-livestock farms. Regarding the social pillar, these issues are related to the *Indicator 27 – Livestock management* and, partially, to the *Indicator 32 – Sustainable use of materials*.

Facing to these problems is one of the main issues in the agricultural evaluation of sustainability and the heterogeneity of the farming systems represents a strong obstacle. The solution is conceptual rather than methodological, since any decision may be subject to criticism and does not appear possible the adaption of an approach which would break all the problems. Mediation trying to choose the least bad solution would seem the best choice. In this case, the choices could be:

- do not make any changes. The presence of indicators focused on the livestock management makes null result for farms that do not breed animals. The grain producers, for examples, are penalized for the absence of breeding and this is justified with the negative incidence the diversity and the dependence from the outside for the raw materials (e.g. organic fertilizers);
- creating a separate approach. Livestock farms and no-livestock farms are evaluated through two separate framework appositely studied for their different condition. This approach appears the more correct but it involves relevant difficulties. Firstly, the presence of two or more frameworks rises the methodological complexity and it removes one of the first objective of the research: the creation of a unique approach. Secondly, since it has been considered the creation of a separate evaluation for livestock farms and no-livestock farms, it could been argued that relevant differences exist among livestock systems and, similarly, among cereal systems as well. Thus, the study should evolve in the direction of the creation of more than two approaches. This solution leaves space for unexplored scenarios;
- a third approach is based on a flexible output choice. The database has been structured in a way that in presence of different type of farm, indicators are re-balanced in order to avoid the calculation of the indicator descripted above, but without penalizing those farms. By this way, the sum of the components' maximum score remains fixed [50]. This solution could be criticisable from the scientific point of view because the removal of such indicators and the consequent rebalancing of the others involves the lack of the significance of the initial weight attribution. Nevertheless, it allows an integrate approach without the use of complex approaches.

In the phase of discussion of the results of this study, it will be motivated the chosen approach in relation to the relative type of analysis.

# Chapter 4.

# Discussion and conclusions

---

**Content of this chapter:**

The results derived from the scores of indicators can be visualized by the *Farm ranking approaches*, tools able to compare farm's performances comparing single farms, homogeneous groups of them or the same farm during time. A statistical analysis has been proposed in order to analyse the methodological significance and his possible improvement.

---

## 4.1 Farm ranking approaches

Means of processing and displaying results of this type of indicators by a descriptive analysis are countless. Studies that have adopted similar approaches have presented various solutions (Häni et al., 2003; Meul et al., 2008; Vilain et al., 2008; Zahm et al., 2008; Thivierge et al., 2014; Parrachini et al., 2015). In the following paragraphs, some of these methodologies are descripted, by pillar aggregation, in order to offer an exhaustive framework.

For this case study, scores of the sampled farms are reported in the Appendix A, B and C.

### 4.1.1 Ranking farms by environmental performances

When survey in focussed on the evaluation of the overall performance of farms in one of the three pillars (5 components), spider (or radar) diagrams are able to provide an exhaustive framework (Bockstaller et al., 1997; Girardin et al., 1999; Rigby et al., 2001; Von Wirén-Lehr, 2001). Results are expressed by scores; for each component, the centre is the lowest score [0], while the outer ring corresponds to the higher score [50].

The framework is able to provide different approaches of farm ranking in relation to the sample features, because of its capacity to facilitate the comparison of results (Vilain et al., 2008). This approach is particularly useful when the assigned weight of each element (in this case named "components") is equal (Bockstaller et al., 1997).

Figure 4.1 shows the average performance of the whole sample. The mean scores of each component was rather equal and the total average score of the environmental pillar achieved the value of 96,62 out of 250.

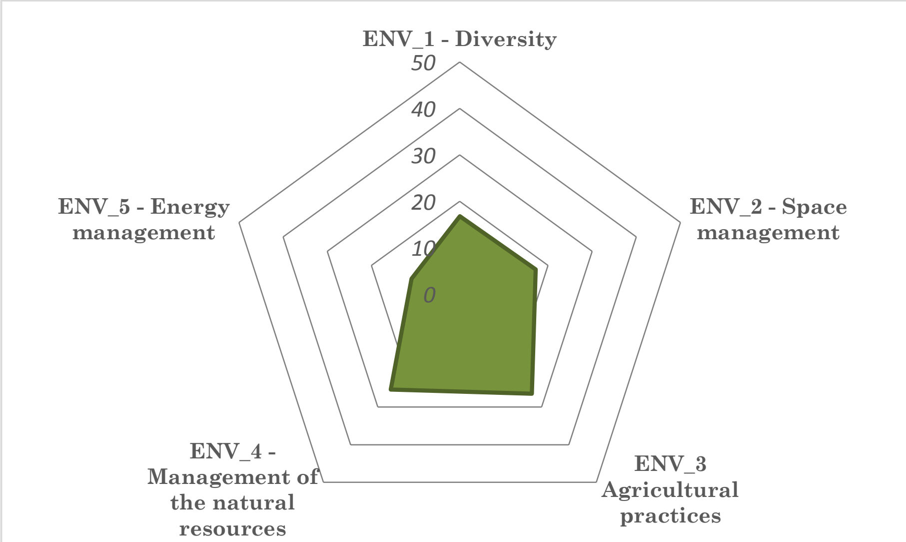



*Figure 4.1: Environmental radar diagram of farms' average performances*

***Farms comparison by ranking of components.*** As suggested by Vilain et al. (2008), a farm's performance can be evaluated through the comparison between its results and the average scores of farms with similar characteristics. For example, Figure 4.2 shows a possible application of this type of approach: the environmental performances of a dairy farm has been compared to the results derived from the average scores of farms of the same productive sector.

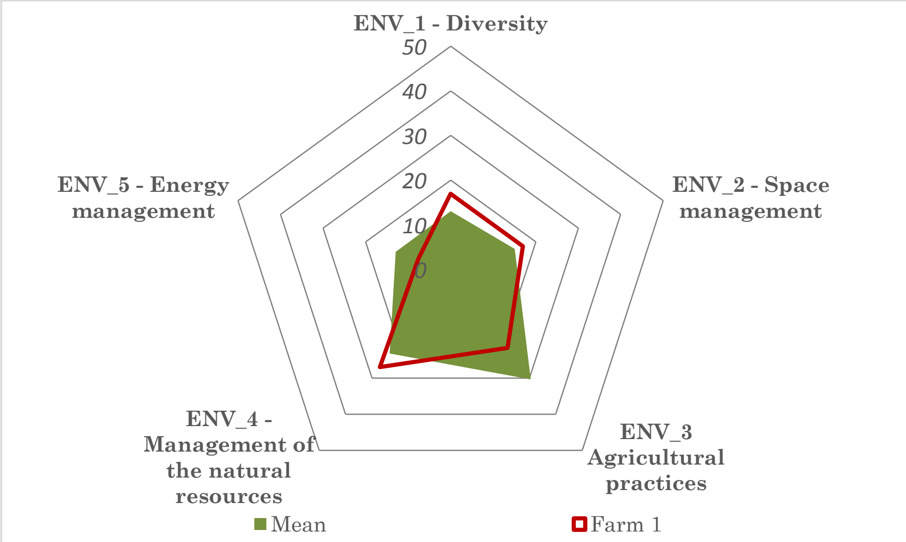



*Figure 4.2: Environmental radar diagram – Farms comparison by ranking of components*

***Farms comparison by ranking of aggregate components.*** The evaluation of the overall performance of farms in the 5 components of each pillar could be performed by the aggregation of homogeneous groups. The following figures show the farms' results, classified by type of production (conventional vs organic) (Figure 4.3) and the level of multifunctionality (Figure 4.4). According to the issue (iii) illustrated in the Paragraph 3.10, the presented outputs derives from the average results of the whole sample, in which the indicators are re-balanced in order to integrate farms, both with livestock and without livestock. The ponderation of the indicators of farms with no breeding or, however, with less than 5 LUs ("Livestock Units"), was conducted through the removal of the following indicators: *9 – Stocking rate*, *12 – Veterinary treatments* and *13 – Management of the livestock effluents*. Consequently, the weights of the remaining indicators, belonging to the *ENV_2* and *ENV_3* components, were recalculated.

In Figure 4.3, the comparison involves the environmental performances of conventional and organic farms. The significance of this assessment may seem relatively minor, especially considering that the most sensitive environmental data derives from interviews, not from direct measurements. In fact, as expected the differences between the two types of production were considerable. However some observations seem interesting. Organic farms achieved higher scores in any component, with exception of the *ENV_5 - Energy management*. Results are in line to what found by Paracchini et al. (2015) that evaluated even higher performances of conventional farms in their correspondent energy use assessment. At the first sight, it could be assumed that the average larger size of conventional farms has a positive impact on the energy dependence. Nevertheless, results derived from data elaboration by surface size or SO (Standard Output) don't allow to prove this statement.

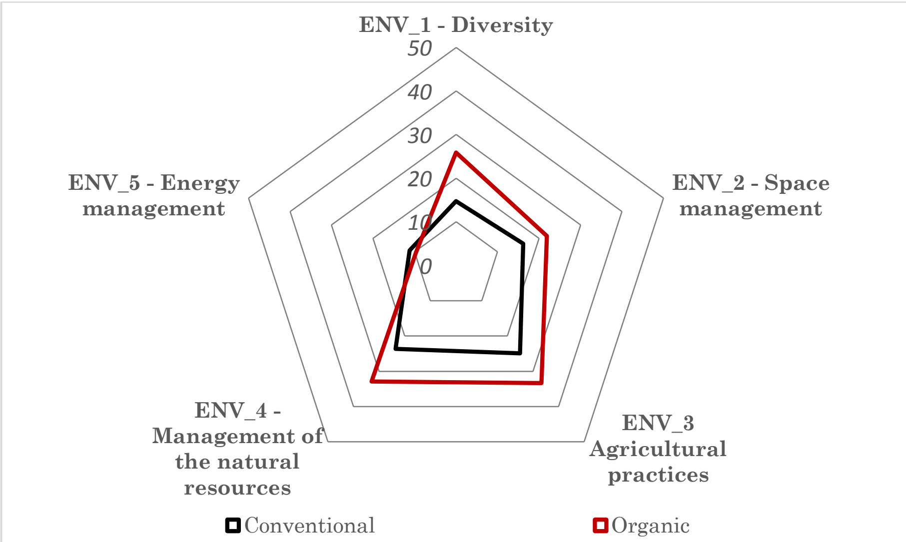



*Figure 4.3: Environmental radar diagram of conventional vs organic farms' average performances*

The sample classification according to the level of multifunctionality was arbitrary, since farms were considered as "non-multifunctional" when no one related activities contributed to the farm income, on the contrary, the presence of one or more of this type of activities has led to the classification of the farm as "multifunctional". On the consequence, different level of multifunctionality are included in this category. Relevant differences between non-multifunctional and multifunctional farms were observed in the first two components, while the other three were very similar (Figure 4.4). This means that the multifunctional attribute does not lead to a better use of inputs (fertilizers, agrochemical, energy, etc.) but it has relevant reflections on the quality of the landscape and the environment, since the *ENV_1 - Diversity* (18,7 vs 12,2 points) and the *ENV_2 - Space management* (18,1 vs 15,1) components achieved higher values.

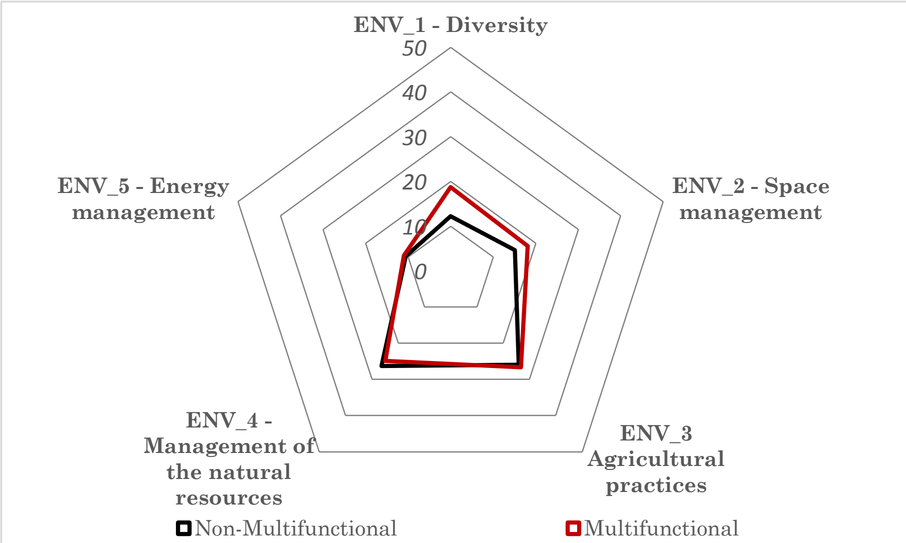



*Figure 4.4: Environmental radar diagram of non-multifunctional vs multifunctional farms' average performance*

### 4.1.2 Ranking farms by social performances

The scores of the *Indicator 27 – Livestock management* and the *Indicator 32 – Sustainable use of materials* were re-balanced, according to the integration process of livestock and non-livestock farms explained in the previous paragraph.

***Farms comparison by ranking of indicators.*** If the case study is focused on single sustainability aspects of individual farms, the method allows an in-depth analysis of farms through the evaluation of the basic indicators. When the work is aimed at the comparison among farms, this approach is able to provide information about components and indicators. In this case, the output is particularly interesting when the comparison involves farms with similar characteristics. Figure 4.5 shows a possible application of the results of two farms. Farm 1 has a conventional production system, the livestock are cattle for milk production and the land area is large. Farm 2 has the same characteristics but it also practises multifunctional activities, while Farm 1 can be defined as non-multifunctional. These two farms are discussed as an example of how the method performs and how data can be interpreted to identify key actions to be adopted to improve farm performance. In general, farmers who have direct contact with consumers achieve higher social results that can also lead to higher environmental performance (Gafsi and Favreau 2010). In our sample, Farm 2 obtained higher scores in the *SOC_2*, *SOC_3* and *SOC_5* components while Farm 1 showed better scores in the *SOC_4* component. The *SOC_2 - Short food supply chain related activities* component result is a direct consequence of the different characteristics on multifunctionality. The third component (*SOC_3 – Work*) underlined the higher contribution of the multifunctionality to the employment in the rural context. On the contrary, the other components seem to be less dependent on the multifunctionality level. Their scores are probably more influenced by other farm characteristics such as land area, the type of production or the management choices of each farm. However, both farms could improve their sustainability level in the *Quality of the products and the territory (SOC_1)* and *Work (SOC_3)*. Farm 1 seems to show no interest in the diversification of the income and the activities. Both farms showed high performance in the ethic and human development (*SOC_4*) and the social, cultural and ecological sustainability (*SOC_5*).

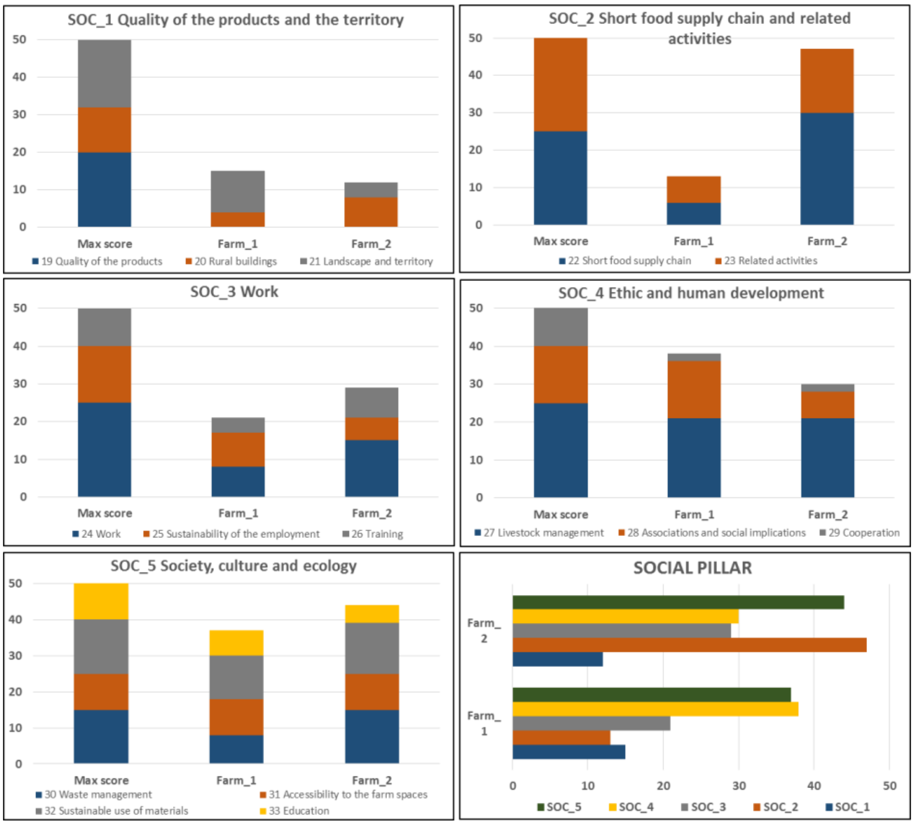



*Figure 4.5: Decomposition of the social pillar into 5 components and the related indicators for two dairy farms*

Figure 4.6 shows the distribution of the scores of the whole sample for each social component. Even in this case, the distribution of the scores was rather homogeneous. The social pillar achieved the average total value of 109,70 out of 250.

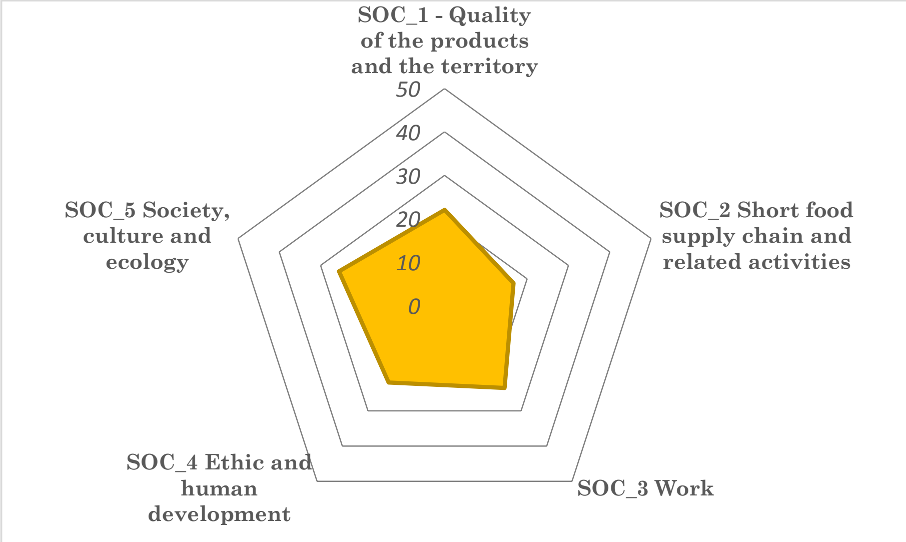



*Figure 4.6: Social radar diagram of farms' average performances*

***Farms comparison by ranking of aggregate components.*** The following figures show the farms' results, classified by production system (Figure 4.7), land area (Figure 4.8) and type of production (conventional vs organic) (Figure 4.9).

In Figure 4.7, the sample is divided into five categories of production system. Cereal and horticultural farms ("No livestock") are characterized by lower average performances. Cattle farms showed generally lower values, in particular for meat production. These are often large farms that are not interested and do not have the necessary conditions to diversify production and to develop systems of short chain and related activities. In the *SOC_2 - Short food supply chain and related activities* component, they achieved an overall score of 19 and 20 respectively for milk and meat production, while poultry achieved 29.5 out of 50. This is probably because their product types are often sold to only a few large clients. On the contrary, pigs and especially poultry farms achieved the highest average values in almost all components, because of the diversification of production and income and the greater ability to offer sales services and other social functions. Similar results were noticed in the *SOC_3 -Work* component. This is probably due to the higher level of multifunctionality of these farms, rather than a greater demand for workers with livestock that leads to a higher contribution to employment. On the other hand, the *SOC_4 - Ethic and human development* and the *SOC_5 - Society, culture and ecology* components are characterized by higher scores in the cattle, particularly for dairy farms and the pigs samples. This result is rather interesting and suggests the need for further evaluation. The fact that the high level of knowledge requested for these types of systems could also influence education and culture or that, traditionally, these farmers are more involved in innovation processes are only two of many potential interpretations.

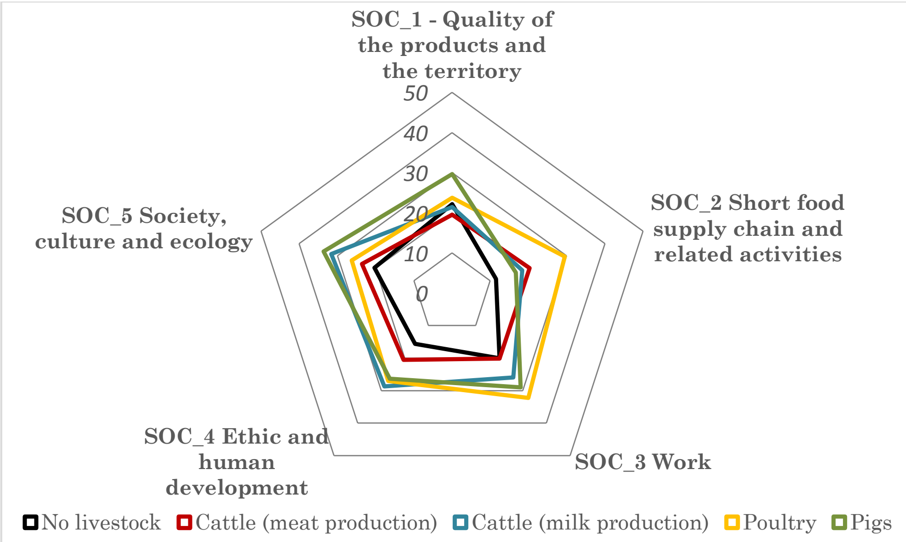



*Figure 4.7: Radar diagram of No livestock vs Cattle (meat production) vs Cattle (dairy farms) vs Poultry vs Pig farms' average performances*

Figure 4.8 shows the results of the farms, aggregated by area classes. Only few differences were noted. In particular, the *SOC_2* component seems to allow some relevant considerations; smaller farms tend to achieve higher results (22.9 out of 50), because of their predisposition in finding different types of income. Nevertheless, this difference was not noted in the whole sample. The results of the *SOC_3 – Work* component seems to not be influenced by the land area of the farms. In the literature, these results have contradictory feedbacks. Our data is in accord with that of Häni et al. (2003), which did not find any substantial difference in the corresponding social component (*Work condition*) of the *RISE Method*. On the other hand, it is in disaccord with Gavrilescu et al. (2012) who, applying the *IDEA Method*, attributed lower scores to family farms compared to legal entities mostly because of their rigidity in creating new jobs, low professional training and a lower minimum wage. Reig-Martinez at al. (2011) found an overall high level of sustainability, even social, of larger farms that could be explained through the opportunity to develop a more diversified range of crops and the generation of sufficient income that has permitted the continuity of agricultural activity. It can be supposed that these great differences are probably due to the high dissimilarity of the samples involved in the studies.

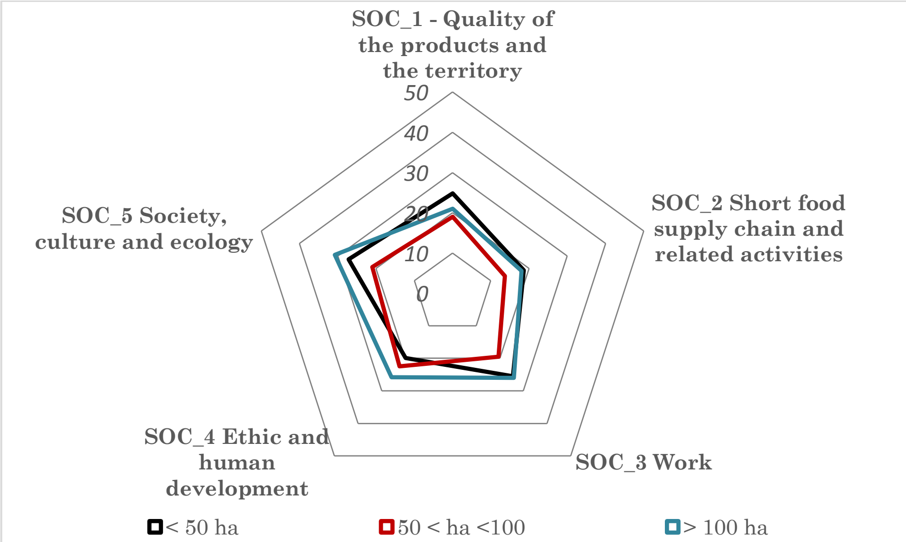



*Figure 4.8: Radar diagram of small (up to 50 ha) vs medium (50 to 100 ha) vs large (more than 100 ha) farms' average performances*

Finally, in Figure 4.9 the social performances of conventional and organic farms are compared. The differences between the two types of production were considerable and even more noticeable here than the environmental pillar: organic farms achieved higher scores in any component. Result of the *SOC_1 – Quality of the products and the territory* component was expected, in consideration of the relevance of the organic certification. The excellent results in the *SOC_2 - Short chain and the related activities* and the *SOC_3 - Work* components are a direct consequence of their higher attitude regard for multifunctionality. These aspects also involve the *SOC_4 – Ethic and human development* and *SOC_5 – Society, culture and ecology* components, as confirmation of the higher level of culture, education and training required for the practice of the organic production.

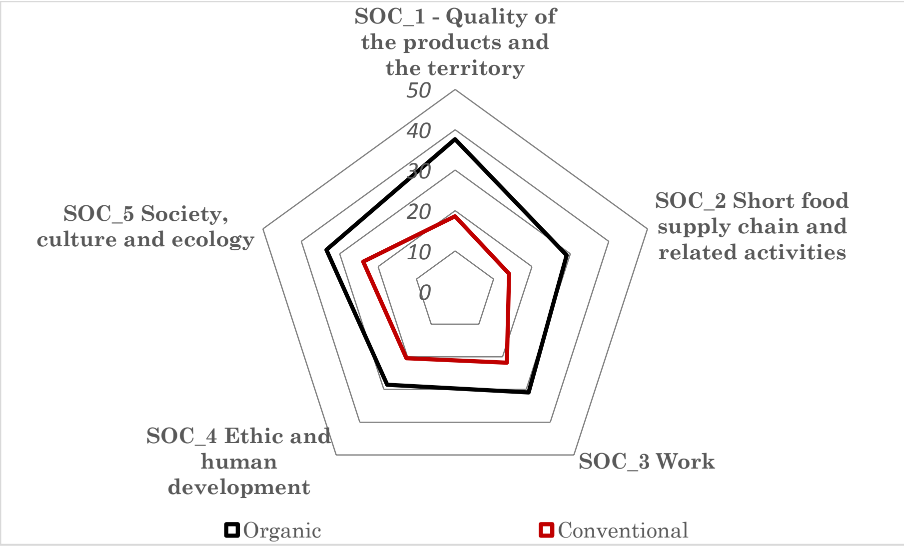



*Figure 4.9: Radar diagram of conventional vs organic farms' average performances*

### 4.1.3 Ranking farms on economic performances

Results of average scores of the economic pillar (Figure 4.10) were less homogeneous comparing to the social and economic ones. In particular, *ECO_4 – Diversification* and *ECO_5 Multifunctionality* components were very different. The average total value was 142,39 out of 250. The economic pillar didn't need any adjustment in order to be more suitable for the type of production of farms, since any economic indicator had not specific characteristic.

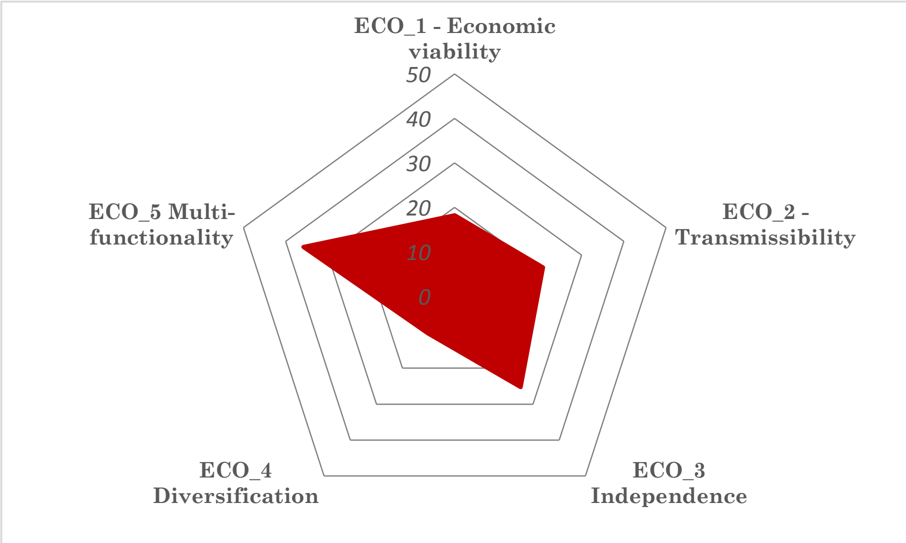



*Figure 4.10: Economic radar diagram of farms' average performances*

***Farms comparison by ranking of aggregate components***. Figure 4.11 shows results of multifunctional and non-multifunctional farms. Apart the normal differences in the two component related to the multifunctional activities of a farm (*ECO_4* and *ECO_5*), the graph showed no particular difference between the samples in the strictly economic component *ENV_1 Economic viability*. This result was in line with what obtained by Paracchini et al. (2015) that, however, found some better performances of multifunctional farms in their respective indicators of "*independence*" and "*farm household income*".

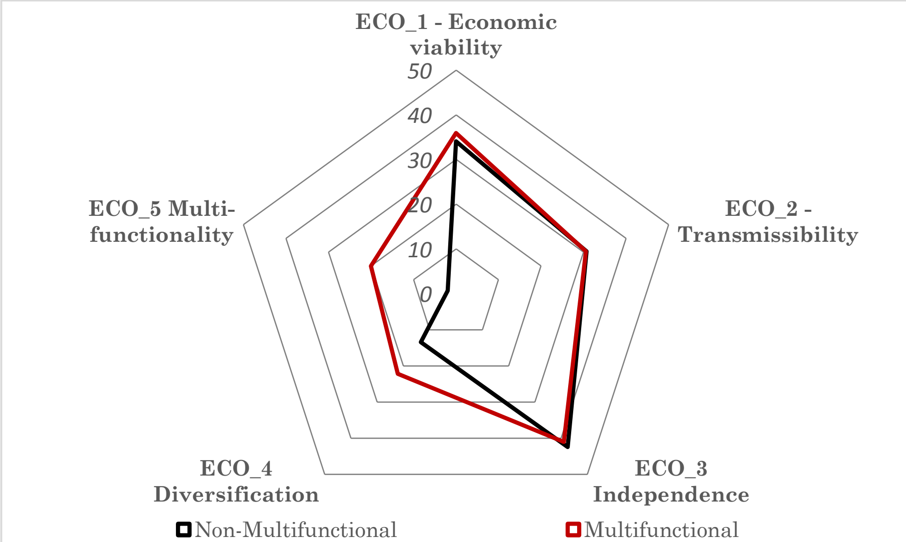



*Figure 4.11: Economic radar diagram of non-multifunctional vs multifunctional farms' average performances*

The classification of the sampled farms in relation to their SO values enables the classification on the base of their ability to generate income (Figure 4.12). In our sample, this classification was very similar to the land surface classification. However, this choice appears most appropriate in order to provide a proper selection of "large", "medium" and "small" farms. This is particularly useful for the classification of multifunctional farms and those with a large livestock but little land surface (this is especially the case of poultry farming). With regard to the economic viability (*ECO_1*), transmissibility (*ECO_2*) and independence (*ECO_3*), largest farms (SO>100) seemed to outperform smallest ones (SO<100). Small farms achieved better results in the *ECO_4 – Diversification* and, particularly, on the *ECO_5 – Multifunctionality* components. The fact that large farms are more sustainable from the economic point of view is in accord to other studies (Häni et al., 2003; Reig-Martinez et al., 2011) and it is probably due to the existence of economies of scale in agricultural productions (Alvarez and Arias, 2004).

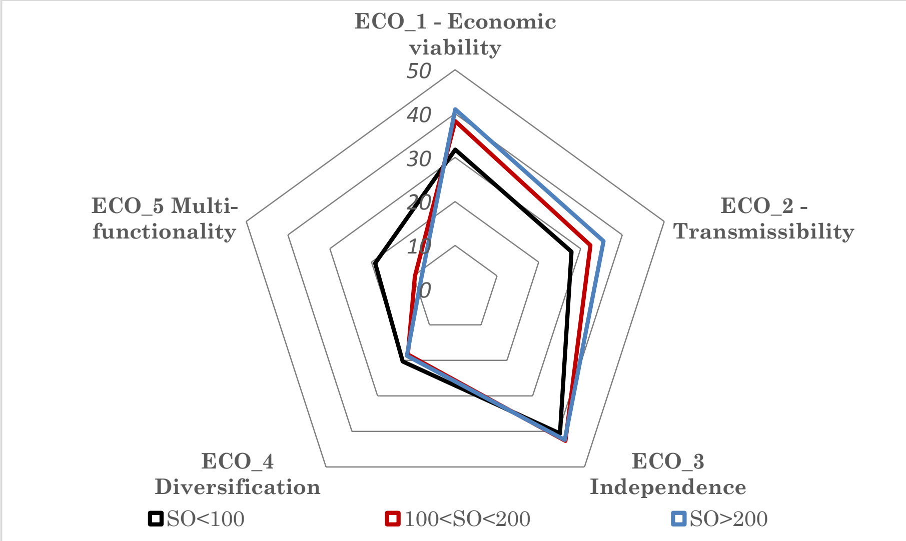



*Figure 4.12: Economic radar diagram of small (SO<100), medium (100<SO<200) and large (SO>200) farms*

### 4.1.4 Alternative available approaches of ranking of farms

Other approaches are available in this framework:

- ***Single indicator evaluation***: the evaluation of a single or few aspects of the environmental, social and economic pillars;
- ***Score evolution***: the temporal comparison looks at the evolution of the 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 farms data for different years, but it is still worth being cited because of its potential multiple utilizations, both at the farm level. For example, farmers could use it to evaluate the trend of their own work, while policy-maker, comparing the performance of different farms systems over time could obtain useful information for decision-making (see paragraph 3.7).

## 4.2 Statistical analysis

The statistical analysis performed in this study was carried out using data provided by the "initial database" (without any re-balancing of the indicators), in which the indicators related to the livestock management (*9, 12, 13, 27* and *32*) were excluded from the survey in order to avoid tainting results.

### 4.2.1 Step 1: Correlation analysis

A correlation matrix among 42 indicators and 3 pillars was created, applying the *Pearson correlation*. Due to its large size, the entire correlation table can not be presented (correlations among indicator of the same pillar are showed in the following Tables 4.1, 4.2 and 4.3). The procedure involved the discussion of correlation within indicators and pillars.

***Correlations within environmental indicators*** (Table 4.1). A *Correlation Analysis* among 15 environmental indicators was carried out on the basis of their scores. Where significant, all correlations were positive. The highest correlations (r>0.50, in red character) were:

- *Indicator 1 – Annual crops diversity* with indicators *5 – Crop rotation* (r=+0,52) and *11 – Pesticides* (r=+0,55);
- *Indicator 5 – Crop rotation* with indicators *2 – Tree crops diversity* (r=+0,59) and *11 – Pesticides* (r=+0,50);
- *Indicator 11 – Pesticides* and *Indicator 16 – Organic matter management* (r=+0,59);
- *Indicator 10 – Fertilization* and *Indicator 17 - Energy dependence* (r=+0,63).

Among indicators of the same component, it is interesting to notice that the indicators of the *Diversity* component (grey area) were all positively correlated (+0,03<r<+0,50), excepting the *Indicator 3 – Animal diversity* that was negatively correlated to the *Indicator 1 – Annual crop diversity* (r=-0,13). The indicators of the *ENV_2 Space management* component (red area) were all positively correlated (+0,02<r<0,34), excepting the *Indicator 7 – Ecological buffer zones* and the *Indicator 9 – Stocking rate* that were negative (r=-0,18). The two indicators of the *ENV_3 Agricultural practices* component (blue area) were negatively correlated (r=-0,11). The *ENV_4 Management of the natural resources* component (green area) showed less correlations (-0,06<r<+0,37) while the two indicators of the *ENV_5 Energy management* component (yellow area) were negatively correlated (r=-0,22).

*Table 4.1: Correlation matrix of the environmental indicators*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1 | ,499** | -0,130 | 0,223 | ,523** | 0,07 | 0,226 | -0,146 | 0,221 | ,551** | 0,058 | ,453** | ,427** | -0,101 | 0,063 |
| **2** | ,499** | 1 | 0,033 | ,411** | ,558** | 0,155 | ,316* | 0,093 | 0,195 | ,427** | ,288* | ,362** | 0,232 | -0,118 | 0,049 |
| **3** | -0,130 | 0,033 | 1 | 0,129 | 0,166 | 0,114 | -0,041 | 0,195 | -,299* | 0,243 | 0,019 | -0,088 | ,332* | -,317* | 0,147 |
| **4** | 0,223 | ,411** | 0,129 | 1 | 0,176 | 0,138 | 0,197 | 0,130 | 0,266 | 0,033 | -0,185 | 0,111 | -0,012 | 0,139 | -0,136 |
| **5** | ,523** | ,558** | 0,166 | 0,176 | 1 | 0,065 | ,339* | 0,070 | 0,105 | ,503** | ,321* | 0,147 | 0,246 | -0,123 | 0,240 |
| **6** | 0,07 | 0,155 | 0,114 | 0,138 | 0,065 | 1 | 0,021 | 0,035 | 0,021 | 0,049 | 0,103 | 0,176 | 0,192 | -0,177 | -0,180 |
| **7** | 0,226 | ,316* | -0,041 | 0,197 | ,339* | 0,021 | 1 | 0,087 | 0,061 | 0,165 | 0,240 | 0,004 | 0 | -0,088 | ,346* |
| **8** | -0,146 | 0,093 | 0,195 | 0,130 | 0,070 | 0,035 | 0,087 | 1 | 0,009 | -0,161 | 0,038 | -0,224 | -0,151 | -0,005 | -0,075 |
| **10** | 0,221 | 0,195 | -,299* | 0,266 | 0,105 | 0,021 | 0,061 | 0,009 | 1 | -0,113 | -0,058 | -0,084 | -0,254 | ,627** | -0,116 |
| **11** | ,551** | ,427** | 0,243 | 0,033 | ,503** | 0,049 | 0,165 | -0,161 | -0,113 | 1 | ,370** | ,377** | ,589** | -,300* | 0,103 |
| **14** | 0,058 | ,288* | 0,019 | -0,185 | ,321* | 0,103 | 0,240 | 0,038 | -0,058 | ,370** | 1 | -0,064 | ,289* | -0,115 | 0,085 |
| **15** | ,453** | ,362** | -0,088 | 0,111 | 0,147 | 0,176 | 0,004 | -0,224 | -0,084 | ,377** | -0,064 | 1 | ,369** | -0,164 | -0,157 |
| **16** | ,427** | 0,232 | ,332* | -0,012 | 0,246 | 0,192 | 0 | -0,151 | -0,254 | ,589** | ,289* | ,369** | 1 | -,444** | 0,167 |
| **17** | -0,101 | -0,118 | -,317* | 0,139 | -0,123 | -0,177 | -0,088 | -0,005 | ,627** | -,300* | -0,115 | -0,164 | -,444** | 1 | -0,215 |
| **18** | 0,063 | 0,049 | 0,147 | -0,136 | 0,240 | -0,180 | ,346* | -0,075 | -0,116 | 0,103 | 0,085 | -0,157 | 0,167 | -0,215 | 1 |

** correlation is significant at the 0.01 level
* correlation is significant at the 0.05 level

***Correlations within social indicators*** (Table 4.2). Indicators of the *SOC_1 Quality of the products and the territory* (grey area) component were all positively correlated, despite not significantly (0,05<r<0,25). The two indicators of the *SOC_2 Short food supply chain and related activities* component (red area) were positively correlated (r=+0,45). The indicators of the *SOC_3 Work* component (blue area) were highly correlated (0,36<r<0,48). The indicator of the *SOC_4 Ethic and human development* component (green area) were also positively correlated, but with a low significance (0,07<r<0,34). Only the *SOC_5 Society, culture and ecology* component (yellow area) showed some uncorrelated indicators. Considering the whole set of social indicators, the most important correlations (r>0.50 or r<-0.50) were:

- *Indicator 23 – Related activities* with the indicators *24 – Work* (r=+0,52), *26 – Training* (r=+0,50), *31 – Accessibility to the farm spaces* (r=+0,68);
- *Indicator 22 – Short food supply chain* with the indicators *24 – Work* (r=+0,60) and *29 – Cooperation* (r=+0,55);
- *Indicator 33 – Education* with the indicators *25 – Sustainability of the employment* (r=+0,50) and *26 – Training* (r=+0,51);
- *Indicator 26 – Training* with the *Indicator 31 – Accessibility to the farm spaces* (r=+0,61).

No relevant negative correlation (r<-0,50) were observed.

*Table 4.2: Correlation matrix of the social indicators*

| | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 28 | 29 | 30 | 31 | 32 | 33 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **19** | 1 | 0,062 | 0,249 | ,286* | 0,183 | 0,175 | ,492** | 0,157 | 0,228 | ,359* | ,452** | 0,120 | 0,04 | ,486** |
| **20** | 0,062 | 1 | 0,049 | 0,264 | 0,177 | 0,099 | 0,017 | 0,263 | 0,139 | 0,256 | 0,237 | 0,173 | 0,038 | 0,229 |
| **21** | 0,249 | 0,049 | 1 | 0,179 | ,447** | ,301* | 0,178 | 0,219 | 0,211 | 0,087 | 0,268 | ,308* | -0,010 | ,306* |
| **22** | ,286* | 0,264 | 0,179 | 1 | ,453** | ,597** | 0,268 | ,369** | ,382** | ,549** | ,392** | ,444** | 0,116 | ,344* |
| **23** | 0,183 | 0,177 | ,447** | ,453** | 1 | ,515** | ,280* | ,503** | ,483** | ,355* | 0,227 | ,684** | 0,205 | ,444** |
| **24** | 0,175 | 0,099 | ,301* | ,597** | ,515** | 1 | ,362** | ,481** | 0,132 | 0,211 | ,345* | ,363** | ,297* | 0,193 |
| **25** | ,492** | 0,017 | 0,178 | 0,268 | ,280* | ,362** | 1 | ,437** | 0,215 | 0,098 | ,493** | ,391** | 0,012 | ,585** |
| **26** | 0,157 | 0,263 | 0,219 | ,369** | ,503** | ,481** | ,437** | 1 | ,314* | 0,113 | ,379** | ,606** | 0,135 | ,511** |
| **28** | 0,228 | 0,139 | 0,211 | ,382** | ,483** | 0,132 | 0,215 | ,314* | 1 | ,335* | 0,213 | ,450** | -0,041 | ,345* |
| **29** | ,359* | 0,256 | 0,087 | ,549** | ,355* | 0,211 | 0,098 | 0,113 | ,335* | 1 | 0,229 | 0,253 | 0,103 | ,293* |
| **30** | ,452** | 0,237 | 0,268 | ,392** | 0,227 | ,345* | ,493** | ,379** | 0,213 | 0,229 | 1 | 0,241 | 0,006 | ,442** |
| **31** | 0,120 | 0,173 | ,308* | ,444** | ,684** | ,363** | ,391** | ,606** | ,450** | 0,253 | 0,241 | 1 | 0,161 | ,549** |
| **33** | ,486** | 0,229 | ,306* | ,344* | ,444** | 0,193 | ,585** | ,511** | ,345* | ,293* | ,442** | ,549** | -0,086 | 1 |

** correlation is significant at the 0.01 level
* correlation is significant at the 0.05 level

***Correlations within economic indicators*** (Table 4.3). The two indicators of the *ECO_1 Economic viability* component (grey area) and the *ECO_2 Transmissibility* component (red area) were positively correlated (r=+0,87 and r=+0,58 respectively), while the indicators of the *ECO_3 Independence* component (blue area) and the *ECO_4 Diversification* component (green area) were less correlated, but still significantly (r=+0,35 and r=+0,43 respectively). The discussion about correlations among the whole set of economic indicators showed a very high positive correlation among the indicators of the first two components (0,55<r<0,87). The only one indicator (*42 – Multifunctionality*) of the *ECO_5 Multifunctionality* component (yellow area) was positively correlated to the *Indicator 41 – Farm business diversification* (r=0,64).

*Table 4.3: Correlation matrix of the economic indicators*

| | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 |
|---|---|---|---|---|---|---|---|---|---|
| **34** | *1* | *,869*** | *,544*** | *,845*** | *,325** | *-0,100* | *-0,058* | *-0,251* | *-0,160* |
| **35** | *,869*** | *1* | *,744*** | *,862*** | *,425*** | *-0,165* | *-0,062* | *-0,115* | *-0,032* |
| **36** | *,544*** | *,744*** | *1* | *,581*** | *,430*** | *-0,162* | *-0,155* | *-0,039* | *-0,039* |
| **37** | *,845*** | *,862*** | *,581*** | *1* | *0,172* | *0,055* | *-0,028* | *-0,204* | *-,297** |
| **38** | *,325** | *,425*** | *,430*** | *0,172* | *1* | *-,351** | *-0,080* | *-0,018* | *-0,046* |
| **39** | *-0,100* | *-0,165* | *-0,162* | *0,055* | *-,351** | *1* | *0,010* | *0,055* | *-0,223* |
| **40** | *-0,058* | *-0,062* | *-0,155* | *-0,028* | *-0,08* | *0,010* | *1* | *,431*** | *0,149* |
| **41** | *-0,251* | *-0,115* | *-0,039* | *-0,204* | *-0,018* | *0,055* | *,431*** | *1* | *,644*** |
| **42** | *-0,160* | *-0,032* | *-0,039* | *-,297** | *-0,046* | *-0,223* | *0,149* | *,644*** | *1* |

** correlation is significant at the 0.01 level
* correlation is significant at the 0.05 level

***Correlations within pillars***: results of the correlation analysis between the three pillars of sustainability (Table 4.4) showed a high correlation between the *Environmental* and the *Social* pillars (r=+0,60); the *Social* and the *Economic* pillars were less correlated (r=+0,37) while the *Environmental* and the *Economic* pillar were not correlated (r=+0,05).

*Table 4.4: Correlation matrix of the pillars' scores*

| | **Environmental pillar** | **Social pillar** | **Economic pillar** |
|---|---|---|---|
| **Environmental pillar** | *1* | *,601*** | *0,052* |
| **Social pillar** | *,601*** | *1* | *,370*** |
| **Economic pillar** | *0,052* | *,370*** | *1* |

** correlation is significant at the 0.01 level
* correlation is significant at the 0.05 level

In general, the survey carried out through the *Correlation Analysis* has shown many significant correlations among indicators belonging to the same component and some correlations among indicators of different components or pillars.

### 4.2.2 Step 2: Principal Components Analysis (PCA) on the indicators' scores

Three *Principal Correspondence Analysis (PCA)* were carried out on the indicators' scores of each pillar.

***PCA on the indicators' scores of the environmental pillar***. The first five components of the *PCA* accounted for a total of 67,52% of the overall variance of the data set (Figure 4.5).

*Table 4.5: PCA scores of the environmental pillar's indicators*

| | Initial eigenvalues | | | Weights of the roteated factors | | |
|---|---|---|---|---|---|---|
| **Principal Component** | **Tot** | **% var** | **% cum** | **Tot** | **% var** | **% cum** |
| **1** | **3,632** | **24,213** | **24,213** | **3,193** | **21,289** | **21,289** |
| **2** | **2,259** | **15,059** | **39,271** | **2,367** | **15,778** | **37,066** |
| **3** | **1,670** | **11,133** | **50,405** | **1,786** | **11,906** | **48,972** |
| 4 | 1,456 | 9,709 | 60,114 | 1,439 | 9,594 | 58,566 |
| 5 | 1,111 | 7,406 | 67,520 | 1,343 | 8,954 | 67,520 |
| 6 | 0,943 | 6,285 | 73,805 | | | |
| 7 | 0,822 | 5,478 | 79,283 | | | |
| 8 | 0,643 | 4,289 | 83,571 | | | |
| 9 | 0,529 | 3,526 | 87,097 | | | |
| 10 | 0,480 | 3,200 | 90,297 | | | |
| 11 | 0,466 | 3,110 | 93,406 | | | |
| 12 | 0,324 | 2,159 | 95,565 | | | |
| 13 | 0,272 | 1,811 | 97,376 | | | |
| 14 | 0,210 | 1,402 | 98,778 | | | |
| 15 | 0,183 | 1,222 | 100,00 | | | |

The first component, that accounted for 21,29% of the total variance, opposed the indicators *1 – Annual crop diversity*, *2 – Tree crops diversity*, *5 – Crop rotation*, *11 – Pesticides* and all other environmental indicators. The second component (15,78% of the total variance) opposed the indicators *3 – Animal diversity*, *10 – Fertilization, 16 – Organic matter management* and *17 – Energy dependence* to all the other indicators. The third component accounted the 11,91% of the overall variance and opposed the indicators *1 – Annual crops diversity* and *8 – Environmental and landscape safeguard* to all other indicators (in particular the *Indicator 15 – Water resource management*). Only the first three components (in red character, which explained the 48,97% of the total variance) of the *PCA* were taken into account for the analysis (Figure 4.6).

*Table 4.6: Principal components of the PCA on the environmental indicators*

| Indicator | Principal component | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| 1 Annual crops diversity | **0,681** | -0,040 | **0,523** | 0,022 | 0,114 |
| 2 Tree crops diversity | **0,811** | -0,019 | 0,049 | 0,181 | 0,074 |
| 3 Animal diversity | 0,111 | **0,688** | -0,341 | 0,065 | 0,186 |
| 4 Safeguard of the genetic diversity | 0,448 | -0,117 | -0,181 | 0,212 | 0,671 |
| 5 Crop rotation | **0,794** | 0,082 | -0,009 | -0,099 | -0,109 |
| 6 Plots management | 0,155 | 0,168 | -0,085 | 0,656 | -0,045 |
| 7 Ecological buffer zones | **0,577** | -0,043 | -0,213 | -0,384 | -0,050 |
| 8 Environmental and landscape safeguard | 0,129 | 0,067 | **-0,720** | 0,186 | 0,091 |
| 10 Fertilization | 0,279 | **-0,775** | -0,041 | 0,089 | 0,129 |
| 11 Pesticides | **0,600** | 0,357 | 0,394 | 0,065 | -0,229 |
| 14 Soil management | 0,396 | 0,060 | -0,141 | 0,117 | -0,817 |
| 15 Water resource management | 0,274 | 0,144 | **0,666** | 0,312 | 0,195 |
| 16 Organic matter management | 0,352 | **0,591** | 0,396 | 0,15 | -0,165 |
| 17 Energy dependence | -0,086 | **-0,815** | -0,093 | 0,027 | 0,085 |
| 18 Renewable Energy | 0,234 | 0,265 | -0,064 | -0,767 | -0,075 |

***Social pillar***: the *PCA* related to the social pillar has led to the definition of five main principal components, that explained a total of 74,49% of the overall variance (Figure 4.7).

*Table 4.7: PCA scores of the social pillar's indicators*

| Principal Component | Initial eigenvalues | | | Weights of the roteated factors | | |
|---|---|---|---|---|---|---|
| | **Tot** | **% var** | **% cum** | **Tot** | **% var** | **% cum** |
| **1** | **4,936** | **37,972** | **37,972** | **2,780** | **21,384** | **21,384** |
| **2** | **1,421** | **10,933** | **48,904** | **2,458** | **18,910** | **40,294** |
| **3** | **1,282** | **9,859** | **58,764** | **1,739** | **13,380** | **53,674** |
| 4 | 1,037 | 7,973 | 66,737 | 1,598 | 12,289 | 65,962 |
| 5 | 1,008 | 7,751 | 74,488 | 1,108 | 8,526 | 74,488 |
| 6 | 0,854 | 6,569 | 81,057 | | | |
| 7 | 0,593 | 4,558 | 85,615 | | | |
| 8 | 0,434 | 3,342 | 88,957 | | | |
| 9 | 0,372 | 2,858 | 91,815 | | | |
| 10 | 0,346 | 2,665 | 94,480 | | | |
| 11 | 0,293 | 2,255 | 96,735 | | | |
| 12 | 0,260 | 1,997 | 98,732 | | | |
| 13 | 0,165 | 1,268 | 100,00 | | | |

Even in this case, the first three principal components were taken into account (53,67% of the total variance). The first component accounted for 21,38% of the overall variance and associated the indicators *23 - Related activities*, *26 - Training*, *28 - Associations and social implications*, *31 - Accessibility to the farm spaces* and *33 - Education*. The second component (18,91%) was defined by the indicators *19 - Quality of the products*, *25 - Sustainability of the employment*, *30 - Waste management* and *33 - Education*. The third component (13,38%) associated the indicators *22 - Short food supply chain* and *24 - Work* (Figure 4.8).

*Table 4.8: Principal components of the PCA on the social indicators*

| Indicator | Principal component 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 19 Quality of the products | -0,008 | **0,769** | -0,027 | 0,423 | -0,18 |
| 20 Rural buildings | 0,144 | 0,081 | 0,080 | 0,207 | 0,807 |
| 21 Landscape and territory | 0,427 | 0,204 | 0,240 | 0,09 | -0,45 |
| 22 Short food supply chain | 0,252 | 0,176 | **0,601** | 0,548 | 0,179 |
| 23 Related activities | **0,773** | 0,060 | 0,364 | 0,231 | -0,081 |
| 24 Work | 0,209 | 0,165 | **0,904** | 0,068 | -0,053 |
| 25 Sustainability of the employment | 0,250 | **0,797** | 0,175 | -0,123 | -0,037 |
| 26 Training | **0,605** | 0,336 | 0,384 | -0,211 | 0,317 |
| 28 Associations and social implications | **0,658** | 0,097 | -0,132 | 0,442 | -0,002 |
| 29 Cooperation | 0,145 | 0,117 | 0,134 | 0,851 | 0,15 |
| 30 Waste management | 0,046 | **0,712** | 0,321 | 0,134 | 0,161 |
| 31 Accessibility to the farm spaces | **0,836** | 0,164 | 0,213 | 0,030 | 0,106 |
| 33 Education | **0,537** | **0,673** | -0,058 | 0,104 | 0,138 |

***Economic pillar***: the first three components of the *PCA* accounted a total of 73,18% of the overall variance of the data set (Figure 4.9). All of them were taken into account.

*Table 4.9: PCA scores of the economic pillar's indicator*

| Principal Component | Initial eigenvalues Tot | %var | %cum | Weights of the roteated factors Tot | %var | %cum |
|---|---|---|---|---|---|---|
| **1** | **3,560** | **39,56** | **39,56** | **3,310** | **36,775** | **36,775** |
| **2** | **1,823** | **20,255** | **59,815** | **1,861** | **20,676** | **57,450** |
| **3** | **1,293** | **14,368** | **74,183** | **1,506** | **16,733** | **74,183** |
| 4 | 0,838 | 9,314 | 83,497 | | | |
| 5 | 0,685 | 7,613 | 91,110 | | | |
| 6 | 0,412 | 4,582 | 95,693 | | | |
| 7 | 0,238 | 2,641 | 98,334 | | | |
| 8 | 0,105 | 1,166 | 99,500 | | | |
| 9 | 0,045 | 0,500 | 100,00 | | | |

The first component (Figure 4.10), accounting the 36,78% of the total variance, opposed the indicators *34 - Value of the production*, *35 - Value added*, *36 - Farm ability to generate income*, *37 - Income per family worker* to the other indicators. The second component, accounting the 20,68% of the total variance, opposed the whole set of indicators to the indicators *40 - Diversification of the production*, *41 - Farm business diversification* and *42 - Multifunctionality*. Finally, the third component (16,73%) opposed the *Indicator 38 - CAP Independence* to the *Indicator 39 - Autonomy*.

*Table 4.10: Principal components of the PCA on the economic indicators*

| Indicator | Principal component 1 | 2 | 3 |
|---|---|---|---|
| 34 Value of production | **0,905** | -0,128 | 0,064 |
| 35 Value added | **0,951** | 0,000 | 0,207 |
| 36 Farm ability to generate income | **0,742** | -0,014 | 0,333 |
| 37 Income per family worker | **0,936** | -0,134 | -0,150 |
| 38 CAP independence | 0,346 | -0,056 | **0,680** |
| 39 Autonomy | 0,006 | -0,034 | **-0,824** |
| 40 Diversification of the production | 0,042 | **0,650** | -0,28 |
| 41 Farm business diversification | -0,102 | **0,907** | 0,004 |
| 42 Multi-functionality | -0,165 | **0,760** | 0,325 |

On the basis of these results, the environmental components have been defined as follow:

- Component 1 (*FAC1 for ENV*): Diversity;
- Component 2 (*FAC2 for ENV*): Energy;
- Component 3 (*FAC3 for ENV*): Safeguard.

The social components have been defined as follow:

- Component 1 (*FAC1 for SOC*): Multi-functionality;
- Component 2 (*FAC2 for SOC*): Quality;
- Component 3 (*FAC3 for SOC*): Work.

The economic components have been defined as follow:

- Component 1 (*FAC1 for ECO*): Productivity;
- Component 2 (*FAC2 for ECO*): Diversification;
- Component 3 (*FAC3 for ECO*): Independence (from subsides).

### 4.2.3 Step 3: Cluster Analysis on the PCA scores

A *Cluster Analysis* was carried out on the basis of the scores of the *Principal Component Analysis*. Three groups identified the economic pillar, while four groups identified both the environmental and the social pillars. Subsequently, the differences between the average scores of each groups and the sample average scores were calculated in order to find out the indicators' significance.

***Environmental pillar***: Among the 15 indicators that define the environmental pillar, 9 of them got relevant differences (>10%) between the group average and the average scores of the whole sample. The *Indicator 3 – Animal diversity* was relevant in distinguish every group and it was very relevant (>20%) in two cases. The indicators *10 – Fertilization*, *16 – Organic matter management* and *17 – Energy dependence* had significant differences in 3 of the 4 groups of the environmental pillar's cluster. On the contrary, the indicators *2 – Tree crops diversity*, *5 – Crop rotation*, *7 – Ecological buffer zones*, *11 – Pesticides*, *15 – Water resource management* and *18 – Renewable energy* didn't assumed relevant differences among groups. The results of the total score of the environmental pillar didn't have relevant difference. On the consequence, no one of the 4 groups could be defined more environmentally sustainable than the others. Groups could be described as follow:

- Group 1 (*C_ENV1*) was composed by 16 farms. As shown in Table 4.11, the cluster was characterized by a higher score in the indicators *1 - Diversity of annual crops* (+12%) and *16 - Organic matter management* (+13%) but a lower score in the indicators *2 - Animal diversity* (-12%), *6 - Plots management* (-11%) and *8 - Environmental and landscape safeguard* (-13%). The average size of their UAA (105,66 ha) and the value of SO (302,05) was higher comparing to the other groups. The production systems were quite heterogeneous since 7 of them were cereal while 6 of them were cattle. According to these characteristics, Group 1 could be described as **"Large production oriented"**;
- Group 2 (*C_ENV2*) was composed by 10 farms. Since 6 of them were cereal farms without any type of livestock, the group was characterized by a very low score (-36%) in the *Indicator 3 – Animal diversity* and a rather low score (-14%) in the *Indicator 16 – Organic matter management*, while getting higher score in the indicators *10 – Fertilization* (+19%) and *17 – Energy dependence* (+17%), because of the lower use of livestock effluents. These results characterized the *C_ENV2* group that it was composed by 10 farms of which 7 of them were cereal farms. Group 2 could be described as **"Vegetal production oriented"**;
- Group 3 (*C_ENV3*) was composed by 12 farms. This group was characterized by a high score of the indicators *3 - Animal diversity* (+18%) and *14 - Soil management* (+13%) while the indicators *1 - Annual crops diversity* (-16%), *10 - Fertilization* (-23%) and *17 - Energy dependence* (-15%) were lower than the average scores. The average land area was the lower among the group (42,53 ha) despite the SO mean

(143,79) was higher than the groups 2 and 4. This is probably because 8 out of 12 has been classified as multifunctional and therefore the related activities could attribute a high weight in the farm's income. The sample is composed mainly by cattle livestock [6]. Group 3 could be described as **"Small production oriented"**;

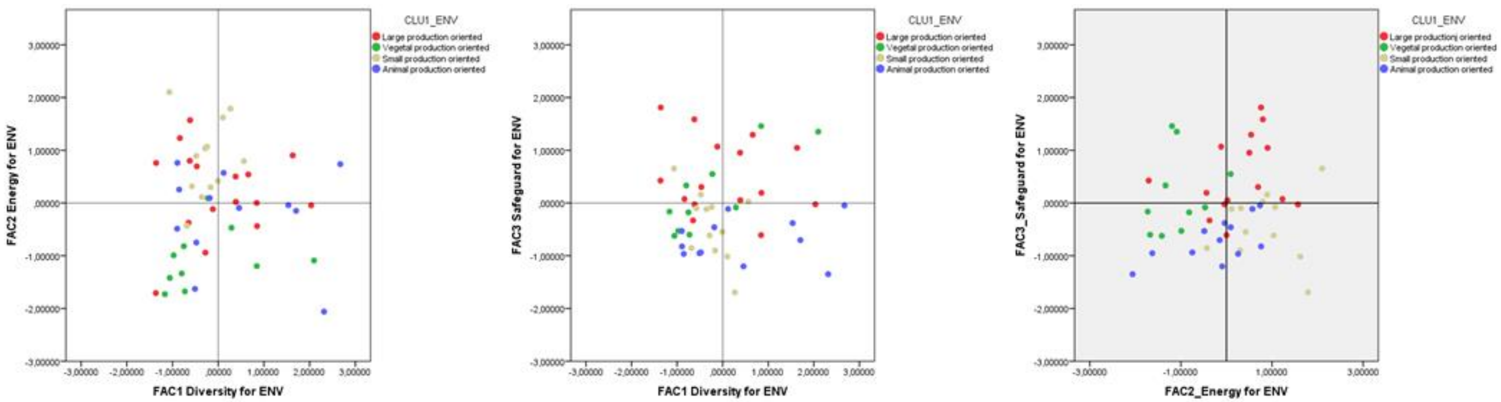
- Group 4 (*C_ENV4*) was composed by 12 farms; 7 of them were livestock. The average score of the *Indicator 3 – Animal diversity* was very highest (+27%) than the average score of the whole sample. Even the indicators *4 – Safeguard of the genetic diversity*, *10 – Fertilization*, *17 – Energy dependence* and *18 – Renewable energy* got higher scores (+27%, +18%, +19% and +11% respectively). On the contrary, the scores of the indicators *14 – Soil management* and *16 – Organic matter management* were lower (-12% and -11% respectively). Group 4 could be described as **"Animal production oriented"**.

*Table 4.11: Significant differences between groups means and the overall mean of the environmental pillar*

| | C_ENV1 | | C_ENV2 | | C_ENV3 | | C_ENV4 | |
|---|---|---|---|---|---|---|---|---|
| **Theme** | **Diff.** | **Sig.** | **Diff.** | **Sig.** | **Diff.** | **Sig.** | **Diff.** | **Sig.** |
| 1 | 0,12 | (+) * | -0,01 | | -0,16 | (-) * | -0,02 | |
| 2 | -0,07 | | 0,05 | | -0,04 | | 0,09 | |
| 3 | -0,12 | (-) * | -0,36 | (-) ** | 0,18 | (+) * | 0,27 | (+) ** |
| 4 | -0,06 | | -0,04 | | -0,07 | | 0,18 | (+) * |
| 5 | 0,05 | | -0,09 | | -0,04 | | 0,07 | |
| 6 | -0,11 | (-) * | 0,06 | | 0,06 | | 0,03 | |
| 7 | 0,05 | | -0,08 | | -0,04 | | 0,04 | |
| 8 | -0,13 | (-) * | 0,03 | | 0,09 | | 0,05 | |
| 10 | -0,06 | | 0,19 | (+) * | -0,23 | (-) ** | 0,19 | (+) * |
| 11 | 0,04 | | -0,07 | | 0,04 | | -0,04 | |
| 14 | -0,02 | | 0,02 | | 0,13 | (+) * | -0,12 | (-) * |
| 15 | 0,06 | | 0,03 | | -0,03 | | -0,08 | |
| 16 | 0,13 | (+) * | -0,14 | (-) * | 0,06 | | -0,11 | (-) * |
| 17 | -0,07 | | 0,17 | (+) * | -0,15 | (-) * | 0,11 | (+) * |
| 18 | 0,08 | | -0,10 | | -0,03 | | -0,01 | |
| TOT | 0,00 | | -0,02 | | -0,03 | | 0,04 | |

* difference between 0,10 and 0,20; ** difference higher than 0,20

The following figures 4.13 (a, b and c) show the groups' distribution among the first three principal component of the environmental pillar. These graphs showed a quite high degree of dispersion of farms belonging to the same groups.




*a* *b* *c*

*Figure 4.13: Environmental groups' distribution: (a) FAC1 – Diversity vs FAC2 - Energy; (b) FAC1 – Diversity vs FAC3 - Safeguard; (c) FAC2 – Energy vs FAC3 – Safeguard*

**Social pillar**: among the 13 indicators that define the social pillar, 12 of them got relevant differences (>10%) between the groups' average scores and the sample's average scores. Only the *Indicator 29 – Cooperation* was not relevant. The *Indicator 23 – Related activities* was always relevant, while the indicator *31 – Accessibility to the farm spaces* was relevant for 3 out of the 4 groups. The amount of the sustainability total score had not very relevant differences excepting the second group that got lowest score (-13%). The four groups could be described as follow:

- Group 1 (*C_SOC1*) was composed by 15 farms. These group got higher scores in the indicators *23 – Related activities* (+16%) and *28 – Associations and social implications* (+14%) while the indicators *20 – Rural buildings* and *26 – Training* were lower (-13% and -11%). Five out of the nine organic farms of the whole sample belonged to this group. Group 1 could be described as **"People-oriented"**;
- Group 2 (*C_SOC2*) accounted 13 farms. This group was characterized by a general lower scores in the main part of indicators (only 2 out of 13 indicators got higher scores, while 11 were negative). In particular, the indicators *26 – Training* and *31 – Accessibility to the farm spaces* were very lower (-22% and -30%). No one indicator was significantly higher. This group seems to not pay particular social interest. Group 2 could be described as **"Business-like oriented"**;
- Group 3 (*C_SOC3*) was the smaller group since it was composed only by 7 farms. Three farms of these group were organic. The indicators *19 – Quality of the products*, *25 – Sustainability of the employment* and *30 – Waste management* were very relevant (+32%, +21% and +34% respectively). On the contrary, the indicators *23 – Related activities* (-22%), *28 – Association and social implications* (-12%) and *31 – Accessibility to the farm spaces* (-25%) were lower. Group 3 could be described as **"Quality production oriented"**;
- Group 4 (*C_SOC4*) was composed by 15 farms. Only positive differences were noticed. In particular, the indicators *23 – Related activities* (+10%), *24 – Work* (+13%), *26 – Training* (+32%) and *31 – Accessibility to the farm spaces* (+29%) were higher than the sample scores. Group 4 could be described as **"Multifunctional activities oriented"**.

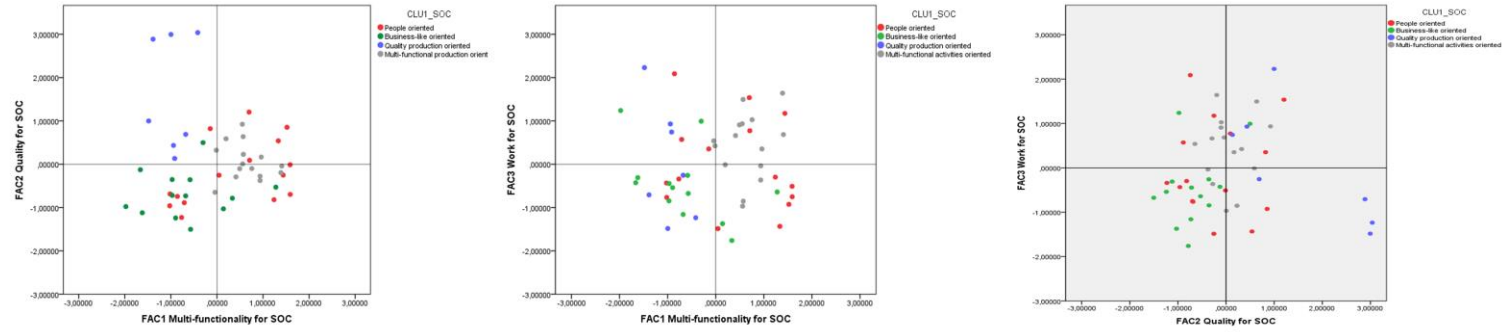
The following figures 4.12 (a, b, c) show the groups' distribution among the first three principal component of the social pillar.

Even in this case, this graphs showed a very high level of dispersion of farms.

*Table 4.12: Significant differences between groups means and the overall mean of the social pillar*

| | C_SOC1 | | C_SOC2 | | C_SOC3 | | C_SOC4 | |
|---|---|---|---|---|---|---|---|---|
| **Theme** | **Diff.** | **Sig.** | **Diff.** | **Sig.** | **Diff.** | **Sig.** | **Diff.** | **Sig.** |
| 19 | 0,09 | | -0,16 | (-) * | 0,32 | (+) ** | -0,10 | |
| 20 | -0,13 | (-) * | 0,08 | | 0,01 | | 0,06 | |
| 21 | 0,08 | | -0,14 | (-) * | 0,06 | | 0,01 | |
| 22 | 0,07 | | -0,10 | (-) * | -0,07 | | 0,05 | |
| 23 | 0,16 | (+) * | -0,18 | (-) * | -0,22 | (-) ** | 0,10 | (+) * |
| 24 | 0,02 | | -0,19 | (-) * | 0,01 | | 0,13 | (+) * |
| 25 | -0,03 | | -0,17 | (-) * | 0,21 | (+) ** | 0,08 | |
| 26 | -0,11 | (-) * | -0,22 | (-) ** | -0,05 | | 0,32 | (+) ** |
| 28 | 0,14 | (+) * | -0,08 | | -0,12 | (-) * | -0,02 | |
| 29 | 0,06 | | 0,03 | | -0,06 | | -0,05 | |
| 30 | -0,04 | | -0,13 | (-) * | 0,34 | (+) ** | 0,00 | |
| 31 | 0,09 | | -0,30 | (-) ** | -0,25 | (-) ** | 0,29 | (+) ** |
| 33 | 0,00 | | -0,17 | (-) * | 0,09 | | 0,10 | |
| TOT | 0,05 | | -0,13 | (-) * | -0,01 | | 0,06 | |

* difference between 0,10 and 0,20; ** difference higher than 0,20




*a* *b* *c*

*Figure 4.14: Social groups' distribution: (a) FAC1 – Multi-functionality vs FAC2 - Quality; (b) FAC1 – Multi-functionality vs FAC3 - Work; (c) FS2 – Quality vs FAC3 - Work*

**Economic pillar**: among the 9 indicators that define the economic pillar, 6 of them got relevant differences (>10%) between the group average and the sample average scores. The *Indicator 42 – Multi-functionality* was always relevant. The indicators *34 – Value of production*, *36 – Farm ability to generate income* and *40 – Diversification of the production* got no relevant differences among the groups. The overall sustainability scores got no significant differences. The 3 groups could be described as follow:

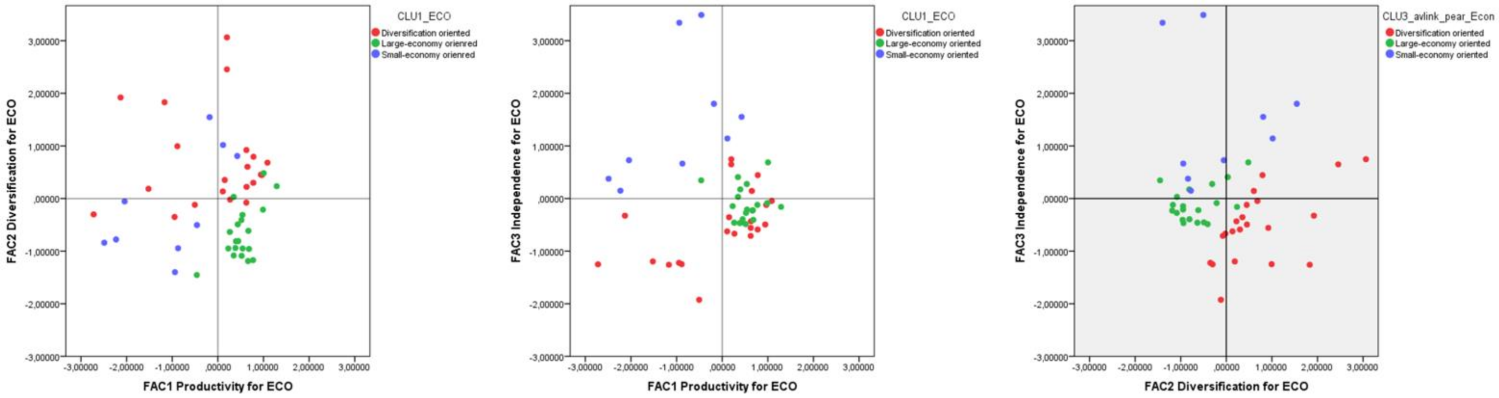
- Group 1 (*C_ECO1*) was composed by 21 farms. The *Indicator 41 – Farm business diversification* and the *Indicator 42 – Multifunctionality* got higher average score comparing to the sample mean (+11% and +13%). These results were in accordance to the sample characteristics, since all of them have been defined as multifunctional. On the consequence, the SO value was high (mean of 186) and the ratio between the SO and the UAA was therefore lower (2,16). Group 1 could be described as "**Diversification oriented"**;
- Group 2 (*C_ECO2*) was composed by 20 farms. The analysis underlined higher scores in the indicators *35 – Value added* (+15%) and *37 - Income per family worker* (+19%) while the indicator *41 – Farm business diversification* and *42 – Multi-functionality* got lower scores (-13% and -21%). Group 2 could be described as "**Large-economy oriented"**;
- the third group (*C_ECO3*) was composed by the other 9 farms. The indicators *35 – Value added*, *37 – Income per family worker*, *39 – Autonomy* got lower scores (-19%, -38% and -19% respectively). The indicators *38 – CAP Independence* (+19%) and *42 – Multi-functionality* (+16%) were higher. These farms were mainly small (UAA mean was 24,59 ha and SO mean was 57,01). Group 3 could be described as **"Small-economy oriented"**.

The following figures 4.15 (a, b, c) show the groups' distribution among the first three principal component of the economic pillar. Unlike the results showed by the other two pillars, the groups of farms highlighted by the scores of clustering of the economic pillar showed a good homogeneity of distribution.

*Table 4.13: Significant differences between groups means and the overall mean of the economic pillar*

| | C_ECO1 | | C_ECO2 | | C_ECO3 | |
|---|---|---|---|---|---|---|
| **Theme** | **Diff.** | **Sig.** | **Diff.** | **Sig.** | **Diff.** | **Sig.** |
| 34 | -0,02 | | 0,06 | | -0,09 | |
| 35 | -0,06 | | 0,15 | (+) * | -0,19 | (-) * |
| 36 | -0,07 | | 0,09 | | -0,05 | |
| 37 | -0,02 | | 0,19 | (+) * | -0,38 | (-) ** |
| 38 | -0,10 | | 0,02 | | 0,19 | (+) * |
| 39 | 0,05 | | 0,03 | | -0,19 | (-) * |
| 40 | 0,10 | | -0,07 | | -0,07 | |
| 41 | 0,11 | (+) * | -0,13 | (-) * | 0,02 | |
| 42 | 0,13 | (+) * | -0,21 | (-) ** | 0,16 | (+) * |
| TOT | 0,02 | | -0,01 | | -0,04 | |

* difference between 0,10 and 0,20; ** difference higher than 0,20




*a* *b* *c*

*Figure 4.15: Economic groups' distribution: (a) FAC1 – Productivity vs FAC2 - Diversification; (b) FAC1 – Productivity vs FAC3 - Independence; FAC2; (c) Diversification vs FAC3 - Independence*

### 4.2.4 Step 4: Indicators reduction by clustering approach

According to Bonneau et al. (2014), a possible method for indicator reduction could be carried out through a "clustering approach". The selection of the significant indicators was based on the principle of significantly of differences (>10%) between average scores of groups and the average scores of the whole sample in at least one of the groups identified by the *Cluster Analysis*. The list of the excluded indicators accounted 10 indicators: seven environmental indicators (*2 – Tree crops diversity*, *5 – Crop rotation*, *7 – Ecological buffer zones*, *11 - Pesticides*, *15 – Water resources management*, *18 – Renewable energy*), one social indicator (*29 - Cooperation*) and three economic indicators (*34 – Value of production*, *36 – Farm ability to generate income* and *40 – Diversification of the production*).

In order to test the method's capacity to provide a significant assessment of sustainability, even without the excluded indicators, the elaboration showed in the Paragraph 4.6.2 and 4.6.3 were repeated for the residual indicators.

***PCA on the significant indicators of the environmental pillar*** (Table 4.14). The environmental pillar were reduced from 15 to 8 indicators. The *PCA* changed and the first four components accounted a total of 69,88% of the overall variance of the data set (Figure 4.14). Three components (that explained 56,38%) of the overall variance have been taken into account.

*Table 4.14: PCA scores on the reduced set of the environmental indicators*

| Principal component | Initial eigenvalues | | | Weights of the roteated factors | | |
|---|---|---|---|---|---|---|
| | Tot | %var | %cum | Tot | %var | %cum |
| **1** | **2,285** | **25,388** | **25,388** | **2,101** | **23,339** | **23,339** |
| **2** | **1,593** | **17,701** | **43,089** | **1,632** | **18,133** | **41,472** |
| **3** | **1,359** | **15,104** | **58,194** | **1,341** | **14,903** | **56,375** |
| 4 | 1,051 | 11,682 | 69,875 | 1,215 | 13,500 | 69,875 |
| 5 | ,876 | 9,738 | 79,613 | | | |
| 6 | ,711 | 7,901 | 87,514 | | | |
| 7 | ,541 | 6,013 | 93,527 | | | |
| 8 | ,319 | 3,546 | 97,073 | | | |
| 9 | ,263 | 2,927 | 100,000 | | | |

The first component, that accounted for 23,34% of the total variance, opposed the indicators *3 – Animal diversity* and *16 – Organic matter management* to the indicators *10 – Fertilization* and *17 – Energy dependence*. The second component (18,13% of the total variance) associated the indicators *1 – Annual crops diversity* and the indicator *16 - Organic matter management*. The third component associated the indicators *4 – Safeguard of the genetic diversity* and *8 – Environmental and landscape safeguard*.

*Table 4.15: Principal components of the PCA on the reduced set of the environmental indicators*

| Indicator | Principal component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 Annual crops diversity | 0,123 | **0,857** | -0,049 | -0,025 |
| 3 Animal diversity | **-0,585** | -0,02 | **0,521** | -0,149 |
| 4 Safeguard of the genetic diversity | 0,244 | 0,345 | **0,534** | -0,525 |
| 6 Plots management | -0,058 | 0,293 | 0,490 | 0,206 |
| 8 Environmental and landscape safeguard | 0,036 | -0,389 | **0,705** | 0,067 |
| 10 Fertilization | **0,860** | 0,194 | 0,127 | -0,055 |
| 14 Soil management | -0,015 | 0,125 | 0,142 | 0,892 |
| 16 Organic matter management | **-0,502** | **0,670** | 0,083 | 0,249 |
| 17 Energy dependence | **0,829** | -0,194 | -0,037 | -0,097 |

***PCA on the significant indicators of the social pillar*** (Table 4.16). Only one indicator (*29 – Cooperation*) was removed from the set of the social indicators. The new *PCA* showed four principal components that explained 68,68% of the total variance.

*Table 4.16: PCA scores on the reduced set of the social indicators*

| Principal component | Initial eigenvalues | | | Weights of the roteated factors | | |
|---|---|---|---|---|---|---|
| | Tot | % var | %cum | Tot | %var | %cum |
| **1** | **4,73** | **39,418** | **39,418** | **2,742** | **22,851** | **22,851** |
| **2** | **1,418** | **11,818** | **51,237** | **2,399** | **19,992** | **42,843** |
| **3** | **1,065** | **8,878** | **60,114** | **1,993** | **16,605** | **59,447** |
| 4 | 1,027 | 8,562 | 68,676 | 1,107 | 9,229 | 68,676 |
| 5 | 0,89 | 7,413 | 76,089 | | | |
| 6 | 0,808 | 6,73 | 82,818 | | | |
| 7 | 0,527 | 4,392 | 87,21 | | | |
| 8 | 0,413 | 3,444 | 90,655 | | | |
| 9 | 0,363 | 3,021 | 93,676 | | | |
| 10 | 0,33 | 2,746 | 96,422 | | | |
| 11 | 0,261 | 2,175 | 98,597 | | | |
| 12 | 0,168 | 1,403 | 100 | | | |

The first three principal components were taken into account (59,48% of the total variance). The analysis was very similar to the first *PCA*. In fact, like the first analysis, the first component accounted for 22,85% of the overall variance and associated the indicators *23 – Related activities*, *26 - Training*, *28 – Associations and* *social implications*, *31 – Accessibility to the farm spaces* and *33 - Education*. Also the second component (19,99%) was defined by the same indicators: *19 – Quality of the products*, *25 – Sustainability of the employment*, *30 – Waste management* and *33 - Education*. Even the third component (16,61%) didn't changed, as it associated the indicators *22 – Short food supply chain* and *24 – Work* (Figure 4.8).

*Table 4.17: Principal components of the PCA scores of the reduced set of the social indicators*

| Indicator | Principal component 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 19 Quality of the products | 0,064 | **0,828** | 0,029 | -0,064 |
| 20 Rural buildings | 0,165 | 0,061 | 0,134 | 0,863 |
| 21 Landscape and territory | 0,414 | 0,216 | 0,268 | -0,386 |
| 22 Short food supply chain | 0,285 | 0,211 | **0,677** | 0,253 |
| 23 Related activities | **0,768** | 0,056 | 0,431 | -0,076 |
| 24 Work | 0,149 | 0,139 | **0,920** | -0,082 |
| 25 Sustainability of the employment | 0,225 | **0,758** | 0,194 | -0,086 |
| 26 Training | **0,541** | 0,254 | 0,412 | 0,218 |
| 28 Associations and social implications | **0,725** | 0,140 | -0,038 | 0,109 |
| 30 Waste management | 0,047 | **0,703** | 0,357 | 0,211 |
| 31 Accessibility to the farm spaces | **0,815** | 0,125 | 0,272 | 0,051 |
| 33 Educations | **0,557** | **0,655** | 0,004 | 0,135 |

***PCA on the significant indicators of the economic pillar*** (Table 4.18). The indicators *34 – Value of production*, *36 – Farm ability to generate income* and *40 – Diversification of the production* were removed. The first three components of the *PCA* accounted a total of 83,33% of the overall variance of the data set (Figure 4.18). All of them were taken into account.

*Table 4.18: PCA scores of the reduced set of the economic indicators*

| Principal component | Initial eigenvalues Tot | %var | %cum | Weights of the roteated factors Tot | %var | %cum |
|---|---|---|---|---|---|---|
| **1** | **2,224** | **37,065** | **37,065** | **1,917** | **31,954** | **31,954** |
| **2** | **1,64** | **27,337** | **64,402** | **1,669** | **27,814** | **59,768** |
| **3** | **1,136** | **18,927** | **83,328** | **1,414** | **23,561** | **83,328** |
| 4 | 0,651 | 10,849 | 94,177 | | | |
| 5 | 0,296 | 4,939 | 99,116 | | | |
| 6 | 0,053 | 0,884 | 100 | | | |

The removal of 3 out of 9 economic indicators didn't cause significant changing in the new *PCA*. The first component (Figure 4.19), accounting the 31,95% of the total variance, associated the indicators *35 – Value added* and *37 – Income per family worker*. The second component, accounting the 27,81% of the total variance, opposed the whole set of indicators to the indicators *41 – Farm business diversification* and *42 – Multi-functionality*. Finally, the third component (23,56%) opposed the *Indicator 38 – CAP Independence* to the *Indicator 39 - Autonomy*.

*Table 4.19: Principal components of the PCA scores on the reduced set of the economic indicators*

| | Component | | |
|---|---|---|---|
| **Principal component** | **1** | **2** | **3** |
| 35 Value added | **0,943** | 0,003 | 0,255 |
| 37 Income per family worker | **0,950** | -0,189 | -0,055 |
| 38 CAP independence | 0,316 | -0,032 | **0,730** |
| 39 Autonomy | 0,086 | -0,065 | **-0,881** |
| 41 Farm business diversification | -0,041 | **0,908** | -0,108 |
| 42 Multi-functionality | -0,127 | **0,896** | 0,157 |

On the basis of these results, the selected component were mainly attributed by the same of the first *PCA*. The only difference was underlined by a reverse position of the first two component of the environmental pillar:

- Component 1 (*FAC1 for ENVred*): Energy;
- Component 2 (*FAC2 for ENVred*): Diversity;
- Component 3 (*FAC3 for ENVred*): Safeguard.

The social components were defined as follow:

- Component 1 (*FAC1 for SOCred*): Multi-functionality;
- Component 2 (*FAC2 for SOCred*): Quality;
- Component 3 (*FAC3 for SOCred*): Work.

The economic components were defined as follow:

- Component 1 (*FAC1 for ECOred*): Productivity;
- Component 2 (*FAC2 for ECOred*): Diversification;
- Component 3 (*FAC3 for ECOred*): Independence (from subsides).

Following the Step 3 (see Paragraph 4.6.3) a *Cluster Analysis* was carried out on the results of the new *PCA*. Figure 4.16, 4.17 and 4.18 shows a graphic comparison between the results obtained by the first elaboration (with the whole set of indicators), and the results obtained by the second elaboration, with a reduced set of indicators.

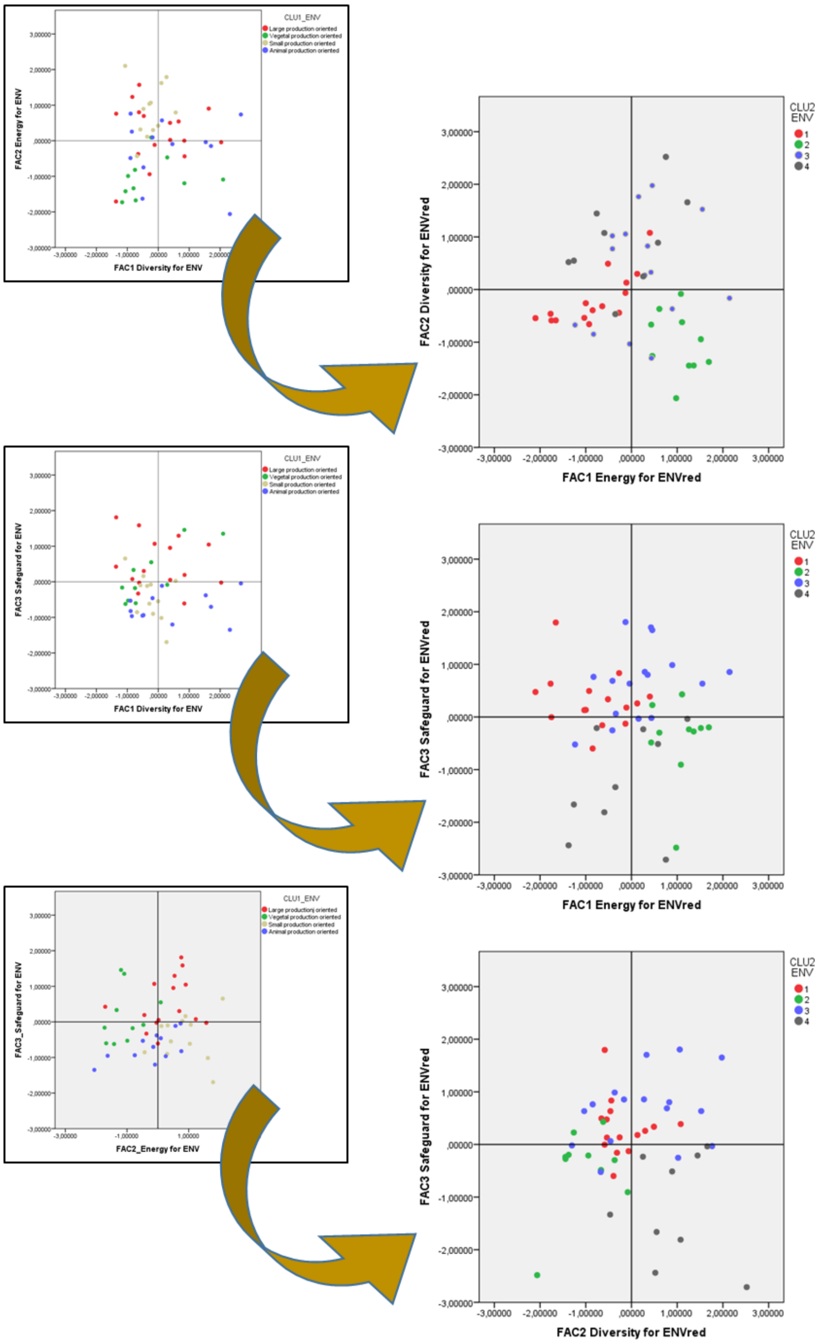



*Figure 4.16: comparison between the environmental maps obtained from the first elaboration, with the whole set of indicators (left side) and the second elaboration, with the reduced set of indicators (right side)*

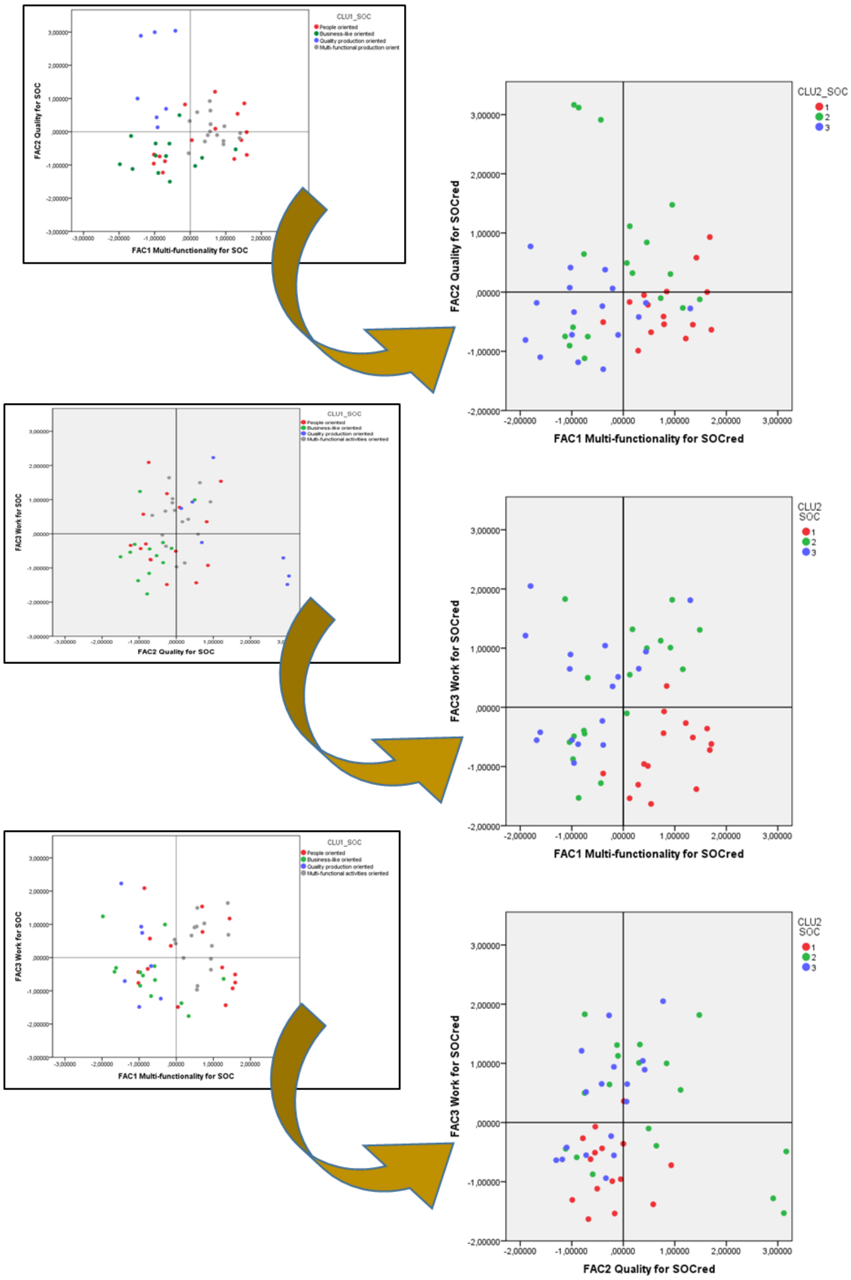



*Figure 4.17: comparison between the social maps obtained from the first elaboration, with the whole set of indicators (left side) and the second elaboration, with the reduced set of indicators (right side)*

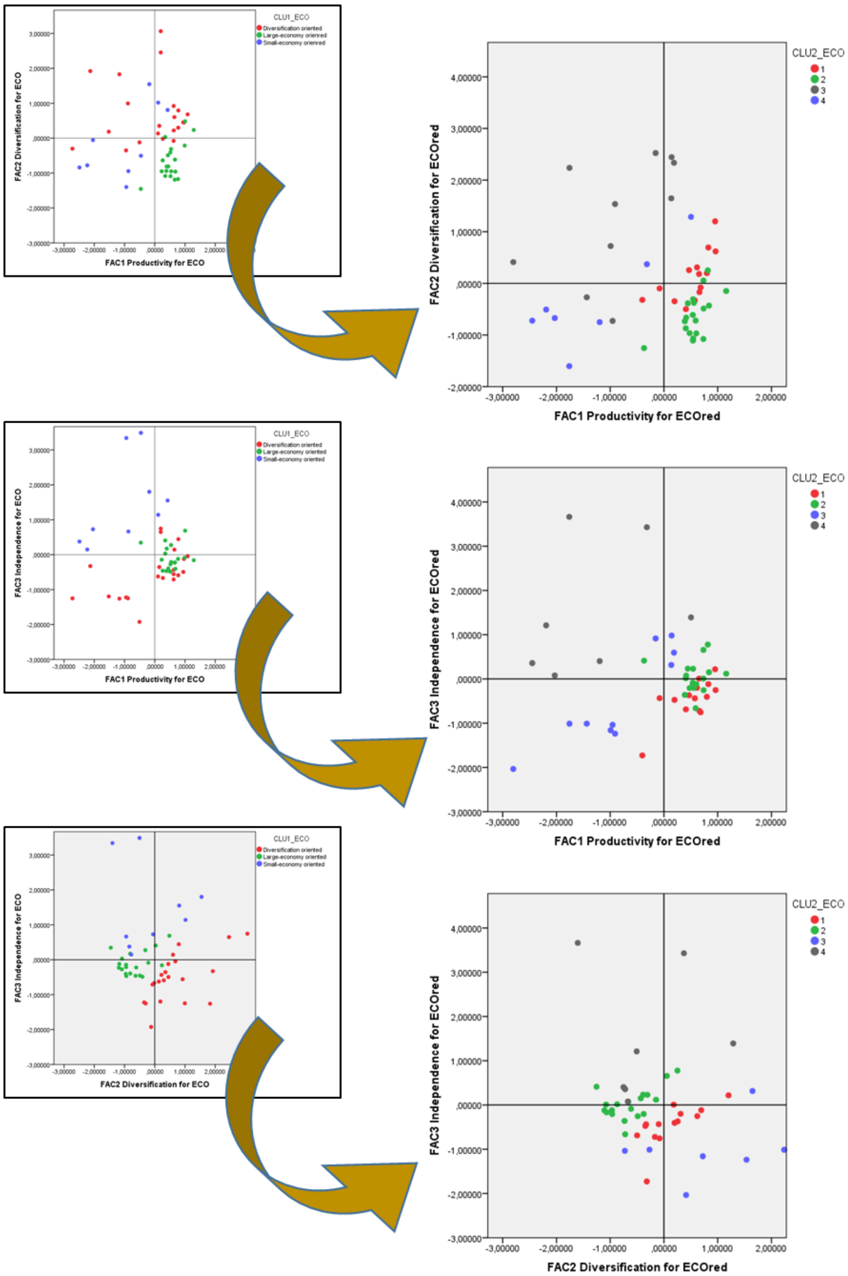



*Figure 4.18: comparison between the economic maps obtained from the first elaboration, with the whole set of indicators (left side) and the second elaboration, with the reduced set of indicators (right side)*

Despite the *PCA* of the reduced set of indicators showed a certain agreement to the first *PCA*, the *Cluster Analysis* didn't show relevant improvement in the group's definition.

### 4.2.5 Discussion on the statistical analysis

The statistical analysis showed a very high variability within farms regarding sustainability. In addition, in many cases, systems belonging to different categories have exhibited very similar strengths and weaknesses, while comparable farms have sometimes showed opposite results. In fact, groups resulting from the *Cluster Analysis* do not fully recover the categories that were considered a priori on the basis of type of production, multifunctionality, land area, value of SO and so on. This could be interpreted as an important sign of sensitivity of the framework, able to assign values of sustainability in relation to the real value of a farm, not following its descriptive information such as the type or production, the land size, etc.

Although some significant correlations were observed within indicators belonging to the same component, there were very few significant correlations between indicators of different components and pillars. This demonstrates that the main part of the initial indicators were important to describe the observed variability among farms and that they were not redundant. Nevertheless, the study highlighted the need to consider that some important correlations left space to the possibility of a reduction of the number of indicators. Moreover, all components contributed to the list of indicators that significantly characterised the groups defined in the *Cluster Analysis*. This demonstrates that all 15 components were important to describe the observed variability among farms and that they were not redundant.

The *clustering process* was used in order to provide a way to simplify the tool. Nevertheless, except for the economic pillar, the definition of the groups was not very satisfactory, even after the repetition of the process for the reduced set of indicators. Since the approach considered in this study for reducing the amount of information was purely based on statistics, no other indication has been taken in order to avoid cancellation of indicators. On the consequence, some of the components were poorly represented by the reduced set of indicators and the indicator reduction was very dissimilar among pillars. In fact, since the reduction of only 1 out of 13 indicators of the social pillar could be considered as insufficient, the reduction from 15 to 8 environmental indicators was probably excessive. In addition, the role of some of these indicators seems to be essential in defining the environmental performances of a farm (e.g. the *Indicator 3 – Tree crops diversity* and the *Indicator 11 – Pesticides*) and the discussion about farm sustainability without taking into account these themes seems to be incomplete.

From a strictly methodological point of view, this approach led to the creation of a reduced set of indicators, from 42 to 32 indicators. This means a relevant reduction of the farm data requested for the analysis. Hence, also the number of basic variables (mainly questions to farmers) were less. Consequently, this means a minor risk in the detection of insured data. However, even other considerations should be taken into account, including time and cost requirement to get information, the willingness of the farmers to be interviewed and provide farm's data, etc. As showed in Table 4.20, the experience derived from this study has let to assert that there were some descriptive parameters that researchers should take into account in order to establish the chance of data reduction:

- *Data source*: when farm's data are available through previous databases (SIARL in this study) in which information are accurate, time wasting is approximately null. In this case, a indicator reduction by statistical process still means data reduction but there is no certainty that this also means time and cost reduction;
- *Data cost*: following this concept, even when data derive from interviews, the farmers' willingness to provide information highly depends from their knowledge, the sensibility of data (economic data particularly) and time consumption;
- *Data linkage*: sometimes, same data are able to provide information useful for the calculation of more than one indicator. In this case, the value of data is considerable as higher and time and cost of information is shared among indicators.

*Table 4.20: Indicators' data source, data cost and data linkage*

| Indicator | Data source | Data cost[1] | Data linkage |
|---|---|---|---|
| 1 Annual crops diversity | SIARL, Quest. | * | 10 |
| 2 Tree crops diversity | SIARL, Quest. | * | 10 |
| 3 Animal diversity | SIARL, Quest. | * | 9; 10; 12 |
| 4 Safeguard of the genetic diversity | Local documents | ** | 1; 2; 3 |
| 5 Crop rotation | SIARL, Quest. | * | 1 |
| 6 Plots management | SIARL, Quest. | * | |
| 7 Ecological buffer zones | SIARL, Quest. | * | |
| 8 Environmental and landscape safeguard | SIARL | * | |
| 9 Stocking rate | SIARL | * | 3; 10; 12; 27 |
| 10 Fertilization | SIARL, Quest. | *** | 1; 2; 3; 9; 17 |
| 11 Pesticides | SIARL, Quest. | ** | 1; 2 |
| 12 Veterinary treatments | Quest. | * | 9; 10 |
| 13 Management of the livestock effluents | Quest. | * | 9 |
| 14 Soil management | Quest. | * | 1 |
| 15 Water resource management | Quest. | ** | |
| 16 Organic matter management | Quest. | * | 9 |
| 17 Energy dependence | SIARL, Quest. | *** | 10; 18 |
| 18 Renewable energy | Quest. | * | 17 |
| 19 Quality of the products | Quest. | * | |
| 20 Rural buildings | Quest. | * | |
| 21 Landscape and territory | SIARL, Quest. | * | |
| 22 Short food supply chain | Quest. | ** | 41 |
| 23 Related activities | Quest. | * | 42 |
| 24 Work | SIARL, Quest. | *** | 25; 33; 34; 35; 36; 37; 38; 39 |
| 25 Sustainability of the employment | Quest. | * | 24 |
| 26 Training | Quest. | * | |
| 27 Livestock management | SIARL, Quest. | ** | 9 |
| 28 Associations and social implications | Quest. | * | |
| 29 Cooperation | Quest. | * | |
| 30 Waste management | Quest. | * | |
| 31Accessibility to the farm spaces | Quest. | * | |
| 32 Sustainable use of materials | Quest. | * | |
| 33 Education | Quest. | * | 24 |
| 34 Value of production | SIARL, Quest. | ** | 24; 35 |
| 35 Value added | SIARL, Quest. | *** | 24; 34 |
| 36 Farm ability to generate income | SIARL, Quest. | *** | 24; 38 |
| 37 Income per family worker | SIARL, Quest. | *** | 24; 37 |
| 38 CAP Independence | SIARL, Quest. | *** | 24 |
| 39 Autonomy | SIARL, Quest. | *** | 24 |
| 40 Diversification of the production | Quest. | ** | 22, 23 |
| 41 Farm business diversification | Quest. | ** | 22, 23 |
| 42 Multi-functionality | Quest. | ** | 22, 23 |

[1] Data cost indication is based on subjective evaluations based on judgments during the data collection: * (not costly), ** (costly), *** (very costly).

These considerations are anyway the result of subjective opinions and, as stated by Bonneau et al. (2014), since the simplification process is dependent on the case study (as the *clustering process* is based on the farm's scores), a in-depth analysis should be considered. In this case, a valid way to check the significance of the statistical approach could be the test of both the complete and simplified tools on a totally different set of farms.

## 4.3 Conclusions

In the present work, 4Agro has been proposed as a new instrument for the evaluation of farm sustainability. The framework was able to provide a valid tool for the evaluation of the environmental, social and economic sustainability of the farms of the case study and to exemplify their strengths and weaknesses. The survey highlighted the procedures and a new approach for the construction of a framework as much as possible compatible to the context and objectives of a circus-wrote region.

From the methodological point of view, the tool was tested on many different farming systems and it provided interesting results. In fact, these output were more sensitive to their effective environmental, social and economic behaviour rather than their structural characteristics. On the consequence, it could be stated that the framework is quite robust and it can be applied to very diverse case studies, regions and farming systems.

In the Paragraph 2.6, after a in-depth analysis of the main issues related to the evaluation of farm sustainability, some relevant questions have been asked. These questions involved important challenging tasks that the many previous studies have avoided or gave just general or incomplete solutions. In order to answer to these issues, the methodological approach adopted in this study has allowed to provide some relevant reflection.

Questions (i) and (ii) were focussed on the issues of rationality in the adoption of a unique framework able to assess sustainability for different environmental, social and economic contexts and different types of farms. The methodological framework here proposed has allowed the use of the same approach for different farming systems. Nevertheless, despite a conceptual correctness, it was evident that adaptations were necessary in order to provide results able to be closer, as much as possible, to the real farms situation. In this case, the main setting involved the creation of different databases in order to provide a proper calculation of any indicators and their consequent re-balancing.

Questions (iii) and (iv) were closely linked to the issues of data requirement. As outlined by this study, the goal of obtaining accurate farms' data is a primary task. It could be often the main problem and this has been proven in this study, during the data collection through questionnaires and interviews. This experience has outlined the problems of availability and sensitivity of the gathering information, which it was already mentioned in other previous studies (Briquel et al., 2001; Viglizzo et al., 2006; Paracchini et al., 2015). To face these issues, the present study has provided a statistical approach able to perform data and indicators reduction. The main objective was to reach an ideal balancing between quality and quantity of information and its cost. While the approach has proven to be methodological-reasonable, its application for the case study has raised some relevant questions about the plausibility to include further variables such as the data source, data cost and data linkage. On the consequence, the approach still remains a subjective decision. In this case, the knowledge of the case study and the objective of the survey.

Finally, the last question (v) involved the capability to create a useful approach at different levels, from farmers to policy-makers, researchers and people in general. The *ranking approaches* proposed in this study offered an exhaustive framework in order to compare the farms' performances. They provide useful information able to satisfy farmers and researchers' goals. Nevertheless, the tool is a valuable support for institutions in order to achieve information about the level of sustainability achieved by farmers, in view of their policy decisions. In this case, the research has highlighted a certain reasonableness in the proposal of assessment of the fourth scale "governance", in order to evaluate the scores obtained in the three pillars. It could be significant to determine the effectiveness of the policy-makers' choices and to correct past errors.

# Chapter 5.

## List of abbreviations, Acknowledgements, References

**Content of this chapter:**

## List of abbreviations

AWU: Annual Work Units
CAP: Common Agricoltural Policy
EBITDA: Earnings Before Interest, Taxes; Depreciation and Amortisation
FWA: Family Working Unit
LCA: Life Cycle Assessment
LUs: Livestock Units
PASM: Parco Agricolo Sud Milano, in English "South Milan Ag-ricultural Park".
PCA: Principal Correspondence Analysis
PDO: Protected Denomination of Origin.
RPD: Rural Development Plan
SIARL: Sistema informativo Agricoltura Regione Lombardia.
SO: Standard Output
UAA: Utilized Agricultural Areas
VA: Value Added
VP: Value of Production

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# Chapter 6.

## Appendices

**Content of this chapter:**

*Appendix A: Environmental pillar, scores*

| ID_farm | UAA | OTE | GEO | SO | BRAND | ORG | LIVES | I_P | MULTI | 1 | 2 | 3 | 4 | ENV_1 | 5 | 6 | 7 | 8 | 9 | ENV_2 | 10 | 11 | 12 | 13 | ENV_3 | 14 | 15 | 16 | ENV_4 | 17 | 18 | ENV_5 | TOT_ENV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENV | 31,4801 | 4110 | 1 | 94,59 | 1 | 1 | 2 | 2 | 2 | 10 | 3 | 5 | 0 | 18 | 14 | 6 | 8 | 3 | 0 | 31 | 14 | 20 | 3 | 1 | 38 | 20 | 8 | 10 | 38 | 5 | 6 | 11 | 136 |
| 2 | 85,1500 | 1320 | 2 | 101,48 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 0 | 0 | 6 | 0 | 6 | 4 | 2 | 0 | 12 | 13 | 10 | 3 | 0 | 26 | 11 | 5 | 6 | 22 | 14 | 2 | 16 | 82 |
| 3 | 40,1083 | 1330 | 3 | 42,82 | 2 | 1 | 1 | 1 | 2 | 8 | 4 | 10 | 0 | 22 | 5 | 6 | 4 | 3 | 6 | 23 | 8 | 19 | 3 | 1 | 31 | 11 | 5 | 10 | 26 | 7 | 6 | 13 | 115 |
| 4 | 73,4676 | 1320 | 2 | 87,46 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 5 | 4 | 11 | 0 | 6 | 6 | 3 | 0 | 15 | 12 | 10 | 3 | 0 | 25 | 5 | 5 | 5 | 15 | 14 | 2 | 16 | 82 |
| 5 | 94,8276 | 4110 | 1 | 345,72 | 0 | 0 | 2 | 2 | 0 | 6 | 3 | 7 | 0 | 16 | 0 | 6 | 4 | 3 | 0 | 13 | 0 | 13 | 0 | 1 | 14 | 17 | 13 | 7 | 37 | 3 | 2 | 5 | 85 |
| 6 | 122,683 | 8120 | 4 | 147,45 | 0 | 0 | 2 | 2 | 1 | 8 | 3 | 9 | 2 | 22 | 3 | 6 | 3 | 3 | 6 | 20 | 10 | 15 | 0 | 1 | 26 | 8 | 5 | 9 | 22 | 4 | 2 | 6 | 96 |
| 7 | 1,4400 | 1310 | 1 | 1,13 | 0 | 1 | 0 | 8 | 0 | 13 | 0 | 0 | 0 | 13 | 1 | 6 | 4 | 0 | 0 | 11 | 15 | 20 | 3 | 0 | 38 | 5 | 20 | 10 | 35 | 12 | 0 | 12 | 109 |
| 8 | 60,0000 | 1443 | 3 | 66,70 | 1 | 0 | 3 | 3 | 1 | 4 | 0 | 14 | 0 | 18 | 0 | 4 | 3 | 3 | 1 | 11 | 15 | 13 | 0 | 0 | 28 | 5 | 5 | 2 | 12 | 13 | 2 | 15 | 84 |
| 9 | 53,5675 | 8130 | 1 | 92,44 | 0 | 0 | 1 | 1 | 0 | 7 | 2 | 5 | 0 | 14 | 2 | 6 | 10 | 3 | 0 | 21 | 2 | 13 | 0 | 0 | 15 | 12 | 5 | 5 | 22 | 4 | 4 | 8 | 80 |
| 10 | 33,2173 | 1320 | 3 | 39,36 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 5 | 0 | 7 | 0 | 6 | 0 | 3 | 0 | 9 | 15 | 10 | 2 | 0 | 27 | 15 | 5 | 7 | 27 | 15 | 2 | 17 | 87 |
| 11 | 13,1290 | 8130 | 1 | 13,20 | 0 | 0 | 1 | 1 | 0 | 5 | 3 | 7 | 0 | 15 | 3 | 6 | 0 | 3 | 6 | 17 | 9 | 15 | 2 | 0 | 26 | 8 | 5 | 5 | 18 | 4 | 2 | 6 | 82 |
| 12 | 6,1282 | 5013 | 1 | 22,16 | 0 | 0 | 1 | 6 | 1 | 2 | 3 | 14 | 0 | 19 | 0 | 6 | 0 | 3 | 0 | 9 | 0 | 13 | 0 | 0 | 13 | 10 | 20 | 10 | 40 | 0 | 2 | 2 | 83 |
| 13 | 32,2154 | 4210 | 4 | 3,15 | 0 | 0 | 1 | 1 | 0 | 1 | 3 | 10 | 0 | 14 | 0 | 6 | 6 | 3 | 6 | 20 | 10 | 15 | 2 | 0 | 27 | 20 | 5 | 10 | 35 | 7 | 0 | 7 | 103 |
| 14 | 214,3410 | 5013 | 0 | 839,95 | 0 | 0 | 4 | 4 | 0 | 4 | 2 | 5 | 0 | 11 | 0 | 6 | 3 | 0 | 0 | 9 | 2 | 10 | 2 | 1 | 15 | 9 | 10 | 6 | 25 | 0 | 6 | 6 | 66 |
| 15 | 30,6044 | 5012 | 4 | 163,69 | 1 | 0 | 4 | 4 | 2 | 2 | 1 | 7 | 0 | 10 | 0 | 5 | 5 | 3 | 0 | 13 | 8 | 13 | 0 | 1 | 22 | 0 | 7 | 8 | 15 | 0 | 10 | 10 | 70 |
| 16 | 51,1100 | 1320 | 2 | 60,19 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 4 | 0 | 0 | 3 | 3 | 0 | 6 | 11 | 10 | 3 | 0 | 24 | 5 | 6 | 0 | 11 | 14 | 2 | 16 | 61 |
| 17 | 72,5669 | 4110 | 1 | 184,83 | 0 | 0 | 2 | 2 | 0 | 7 | 3 | 5 | 0 | 15 | 3 | 6 | 12 | 3 | 1 | 25 | 11 | 13 | 2 | 1 | 27 | 17 | 7 | 8 | 32 | 5 | 8 | 13 | 112 |
| 18 | 115,3200 | 4110 | 3 | 540,60 | 0 | 0 | 2 | 2 | 1 | 6 | 3 | 5 | 0 | 14 | 3 | 6 | 0 | 3 | 6 | 17 | 10 | 13 | 2 | 1 | 26 | 15 | 5 | 8 | 28 | 4 | 2 | 6 | 91 |
| 19 | 309,6085 | 1330 | 2 | 424,72 | 3 | 0 | 2 | 2 | 1 | 9 | 5 | 5 | 2 | 21 | 0 | 5 | 11 | 2 | 2 | 20 | 11 | 15 | 2 | 1 | 29 | 12 | 5 | 7 | 24 | 11 | 10 | 21 | 115 |
| 20 | 21,4780 | 4110 | 3 | 122,28 | 1 | 0 | 2 | 2 | 1 | 3 | 4 | 7 | 0 | 14 | 0 | 6 | 6 | 3 | 0 | 15 | 5 | 15 | 2 | 0 | 22 | 12 | 11 | 7 | 30 | 0 | 6 | 6 | 87 |
| 21 | 43,4700 | 4110 | 1 | 164,79 | 0 | 0 | 2 | 2 | 0 | 5 | 3 | 5 | 0 | 13 | 3 | 6 | 4 | 1 | 0 | 14 | 0 | 15 | 2 | 1 | 18 | 11 | 11 | 9 | 31 | 4 | 2 | 6 | 82 |
| 22 | 163,7160 | 1320 | 3 | 190,65 | 1 | 0 | 0 | 0 | 1 | 6 | 1 | 14 | 0 | 21 | 0 | 6 | 4 | 3 | 0 | 13 | 16 | 13 | 2 | 0 | 31 | 10 | 5 | 10 | 25 | 13 | 6 | 19 | 109 |
| 23 | 50,6861 | 1330 | 1 | 58,00 | 2 | 0 | 0 | 0 | 2 | 6 | 14 | 0 | 4 | 24 | 11 | 6 | 12 | 3 | 0 | 32 | 17 | 10 | 3 | 0 | 30 | 11 | 9 | 0 | 20 | 14 | 6 | 20 | 126 |
| 24 | 48,6600 | 4110 | 2 | 297,95 | 2 | 0 | 2 | 2 | 1 | 4 | 3 | 14 | 0 | 21 | 4 | 6 | 8 | 3 | 0 | 21 | 0 | 15 | 2 | 0 | 17 | 16 | 5 | 8 | 29 | 0 | 2 | 2 | 90 |
| 25 | 64,9100 | 4110 | 1 | 223,80 | 1 | 0 | 2 | 2 | 1 | 6 | 2 | 5 | 0 | 13 | 1 | 6 | 5 | 4 | 0 | 16 | 0 | 15 | 2 | 0 | 17 | 10 | 6 | 7 | 23 | 4 | 6 | 10 | 79 |
| 26 | 52,4800 | 1320 | 2 | 67,65 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 6 | 4 | 3 | 0 | 13 | 13 | 10 | 3 | 0 | 26 | 9 | 5 | 0 | 14 | 12 | 2 | 14 | 69 |
| 27 | 70,0100 | 1320 | 3 | 98,37 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 0 | 0 | 6 | 0 | 6 | 5 | 3 | 0 | 14 | 13 | 9 | 3 | 0 | 25 | 8 | 6 | 6 | 20 | 8 | 2 | 10 | 75 |
| 28 | 63,9800 | 4110 | 2 | 477,23 | 1 | 1 | 2 | 2 | 2 | 4 | 3 | 10 | 0 | 17 | 1 | 6 | 6 | 3 | 0 | 16 | 0 | 13 | 2 | 1 | 16 | 6 | 11 | 7 | 24 | 0 | 4 | 4 | 77 |
| 29 | 32,0370 | 1443 | 1 | 18,49 | 3 | 1 | 3 | 6 | 2 | 8 | 14 | 14 | 4 | 40 | 8 | 6 | 10 | 3 | 2 | 29 | 14 | 20 | 2 | 3 | 39 | 13 | 20 | 8 | 41 | 3 | 6 | 9 | 158 |
| 30 | 66,8200 | 1320 | 3 | 80,09 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 6 | 0 | 3 | 0 | 9 | 13 | 13 | 3 | 0 | 29 | 10 | 6 | 0 | 16 | 17 | 0 | 17 | 74 |
| 31 | 45,9200 | 1320 | 2 | 82,66 | 1 | 0 | 3 | 6 | 1 | 2 | 0 | 14 | 0 | 16 | 0 | 6 | 4 | 3 | 2 | 15 | 12 | 10 | 2 | 3 | 27 | 5 | 5 | 5 | 15 | 12 | 8 | 20 | 93 |
| 32 | 2,2700 | 1430 | 1 | 13,77 | 0 | 1 | 0 | 8 | 0 | 14 | 14 | 0 | 0 | 28 | 4 | 6 | 9 | 3 | 0 | 22 | 15 | 20 | 3 | 0 | 38 | 19 | 18 | 10 | 47 | 10 | 0 | 10 | 145 |
| 33 | 6,0000 | 6040 | 1 | 0,00 | 1 | 1 | 0 | 8 | 1 | 14 | 9 | 5 | 0 | 28 | 8 | 6 | 7 | 3 | 2 | 26 | 5 | 20 | 2 | 0 | 27 | 12 | 13 | 10 | 35 | 1 | 6 | 7 | 123 |
| 34 | 54,0400 | 1320 | 2 | 62,66 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 6 | 12 | 3 | 0 | 21 | 14 | 10 | 3 | 0 | 27 | 7 | 5 | 0 | 12 | 13 | 2 | 15 | 77 |
| 35 | 86,1900 | 1330 | 3 | 105,77 | 0 | 0 | 0 | 0 | 1 | 5 | 0 | 0 | 0 | 5 | 0 | 6 | 6 | 3 | 0 | 15 | 15 | 9 | 3 | 0 | 27 | 10 | 5 | 0 | 15 | 12 | 2 | 14 | 76 |
| 36 | 56,5500 | 1310 | 3 | 84,69 | 2 | 1 | 4 | 4 | 1 | 14 | 9 | 10 | 6 | 39 | 5 | 6 | 4 | 3 | 6 | 23 | 14 | 15 | 2 | 0 | 31 | 6 | 5 | 6 | 17 | 5 | 2 | 7 | 117 |
| 37 | 45,4600 | 1310 | 4 | 57,00 | 2 | 0 | 1 | 6 | 2 | 11 | 11 | 14 | 0 | 36 | 11 | 6 | 5 | 3 | 6 | 30 | 16 | 13 | 2 | 1 | 32 | 12 | 5 | 8 | 25 | 10 | 6 | 16 | 139 |
| 38 | 6,4200 | 1310 | 1 | 17,61 | 0 | 0 | 0 | 9 | 2 | 2 | 0 | 12 | 2 | 16 | 1 | 6 | 4 | 3 | 3 | 17 | 4 | 13 | 2 | 1 | 20 | 5 | 5 | 5 | 15 | 7 | 0 | 7 | 75 |
| 39 | 115,2400 | 4110 | 1 | 210,50 | 1 | 0 | 2 | 2 | 1 | 7 | 3 | 5 | 0 | 15 | 5 | 2 | 8 | 3 | 3 | 21 | 5 | 15 | 2 | 1 | 23 | 14 | 5 | 8 | 27 | 8 | 6 | 14 | 100 |
| 40 | 156,8776 | 1320 | 2 | 169,16 | 1 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 3 | 0 | 5 | 4 | 3 | 0 | 12 | 8 | 10 | 3 | 0 | 21 | 15 | 5 | 7 | 27 | 10 | 10 | 20 | 83 |
| 41 | 34,6000 | 1310 | 1 | 36,67 | 1 | 0 | 1 | 1 | 2 | 5 | 3 | 12 | 4 | 24 | 1 | 6 | 7 | 3 | 3 | 20 | 12 | 13 | 2 | 0 | 27 | 13 | 5 | 7 | 25 | 11 | 2 | 13 | 109 |
| 42 | 15,0600 | 1310 | 1 | 15,43 | 0 | 0 | 5 | 5 | 1 | 3 | 3 | 14 | 2 | 22 | 3 | 6 | 8 | 4 | 0 | 21 | 0 | 15 | 2 | 0 | 17 | 13 | 5 | 9 | 27 | 1 | 2 | 3 | 90 |
| 43 | 20,1300 | 6020 | 2 | 279,48 | 1 | 0 | 0 | 9 | 2 | 7 | 11 | 0 | 0 | 18 | 0 | 6 | 5 | 3 | 0 | 14 | 14 | 13 | 3 | 0 | 30 | 12 | 5 | 6 | 23 | 0 | 2 | 2 | 87 |
| 44 | 404,4200 | 4110 | 0 | 1383,68 | 1 | 1 | 2 | 2 | 2 | 8 | 3 | 7 | 0 | 18 | 5 | 4 | 6 | 1 | 0 | 16 | 8 | 20 | 3 | 1 | 32 | 18 | 5 | 10 | 33 | 4 | 10 | 14 | 113 |
| 45 | 18,3236 | 1310 | 1 | 26,80 | 0 | 0 | 0 | 8 | 1 | 12 | 0 | 0 | 2 | 14 | 0 | 6 | 6 | 3 | 0 | 15 | 15 | 10 | 3 | 0 | 28 | 5 | 13 | 10 | 28 | 0 | 2 | 2 | 87 |
| 46 | 36,6200 | 6050 | 1 | 84,17 | 0 | 0 | 0 | 8 | 1 | 11 | 10 | 0 | 4 | 25 | 1 | 6 | 2 | 3 | 0 | 12 | 14 | 15 | 3 | 0 | 32 | 8 | 20 | 9 | 37 | 16 | 0 | 16 | 122 |
| 47 | 5,0000 | 8231 | 2 | 5,95 | 0 | 0 | 0 | 7 | 1 | 3 | 0 | 5 | 0 | 8 | 0 | 6 | 4 | 3 | 0 | 13 | 11 | 13 | 3 | 0 | 27 | 15 | 5 | 0 | 20 | 5 | 4 | 9 | 77 |
| 48 | 94,2100 | 1443 | 4 | 365,47 | 0 | 0 | 3 | 3 | 1 | 14 | 0 | 7 | 0 | 21 | 5 | 6 | 8 | 3 | 0 | 22 | 7 | 13 | 0 | 1 | 21 | 5 | 15 | 7 | 27 | 5 | 6 | 11 | 102 |
| 49 | 119,9100 | 4120 | 4 | 377,95 | 0 | 0 | 2 | 2 | 0 | 7 | 2 | 5 | 0 | 14 | 6 | 6 | 2 | 3 | 1 | 18 | 6 | 13 | 2 | 0 | 21 | 9 | 13 | 7 | 29 | 9 | 2 | 11 | 93 |
| 50 | 76,8122 | 4120 | 2 | 266,12 | 2 | 0 | 2 | 2 | 1 | 6 | 4 | 5 | 0 | 15 | 1 | 5 | 4 | 3 | 0 | 13 | 2 | 13 | 2 | 1 | 18 | 8 | 9 | 7 | 24 | 5 | 6 | 11 | 81 |

*Appendix C: Social pillar, scores*

| ID_Farm | UAA | OTE | GEO | SO | MARC | ORG | LIVES | I_P | MULTIF | 19 | 20 | 21 | SOC_1 | 22 | 23 | SOC_2 | 24 | 25 | 26 | SOC_3 | 27 | 28 | 29 | SOC_4 | 30 | 31 | 32 | 33 | SOC_5 | TOT_SOC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 31,4801 | 4110 | 1 | 94,59 | 1 | 1 | 2 | 2 | 2 | 14 | 8 | 16 | 38 | 17 | 10 | 27 | 11 | 5 | 10 | 26 | 20 | 15 | 2 | 37 | 8 | 10 | 10 | 8 | 36 | 164 |
| 2 | 85,1500 | 1320 | 2 | 101,48 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 12 | 16 | 0 | 2 | 2 | 6 | 3 | 0 | 9 | 0 | 7 | 0 | 7 | 4 | 5 | 0 | 6 | 15 | 49 |
| 3 | 40,1083 | 1330 | 3 | 42,82 | 2 | 1 | 1 | 1 | 2 | 7 | 4 | 14 | 25 | 30 | 20 | 50 | 20 | 5 | 10 | 35 | 19 | 12 | 4 | 35 | 8 | 10 | 9 | 6 | 33 | 178 |
| 4 | 73,4676 | 1320 | 2 | 87,46 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 4 | 12 | 0 | 2 | 2 | 8 | 2 | 6 | 16 | 1 | 15 | 2 | 18 | 4 | 5 | 1 | 2 | 12 | 60 |
| 5 | 94,8276 | 4110 | 1 | 345,72 | 0 | 0 | 2 | 2 | 0 | 2 | 8 | 4 | 14 | 0 | 0 | 0 | 11 | 3 | 2 | 16 | 21 | 0 | 0 | 21 | 4 | 0 | 13 | 4 | 21 | 72 |
| 6 | 122,683 | 8120 | 4 | 147,45 | 0 | 0 | 2 | 2 | 1 | 2 | 8 | 13 | 23 | 5 | 2 | 7 | 20 | 4 | 6 | 30 | 21 | 7 | 0 | 28 | 8 | 0 | 11 | 4 | 23 | 111 |
| 7 | 1,4400 | 1310 | 1 | 1,13 | 0 | 1 | 0 | 8 | 0 | 20 | 4 | 14 | 38 | 0 | 0 | 0 | 8 | 11 | 0 | 19 | 0 | 5 | 0 | 5 | 12 | 5 | 3 | 8 | 28 | 90 |
| 8 | 60,0000 | 1443 | 3 | 66,70 | 1 | 0 | 3 | 3 | 1 | 0 | 4 | 13 | 17 | 18 | 2 | 20 | 14 | 1 | 2 | 17 | 19 | 2 | 2 | 23 | 4 | 5 | 9 | 4 | 22 | 99 |
| 9 | 53,5675 | 8130 | 1 | 92,44 | 0 | 0 | 1 | 1 | 0 | 0 | 4 | 9 | 13 | 0 | 0 | 0 | 11 | 1 | 0 | 12 | 9 | 7 | 0 | 16 | 4 | 5 | 8 | 0 | 17 | 58 |
| 10 | 33,2173 | 1320 | 3 | 39,36 | 0 | 0 | 0 | 0 | 1 | 0 | 8 | 12 | 20 | 5 | 0 | 5 | 6 | 0 | 0 | 6 | 1 | 2 | 6 | 9 | 4 | 5 | 1 | 6 | 16 | 56 |
| 11 | 13,1290 | 8130 | 1 | 13,20 | 0 | 0 | 1 | 1 | 0 | 0 | 4 | 9 | 13 | 0 | 0 | 0 | 8 | 0 | 0 | 8 | 6 | 0 | 0 | 6 | 4 | 5 | 6 | 2 | 17 | 44 |
| 12 | 6,1282 | 5013 | 1 | 22,16 | 0 | 0 | 1 | 6 | 1 | 0 | 8 | 9 | 17 | 27 | 0 | 27 | 17 | 2 | 0 | 19 | 8 | 2 | 2 | 12 | 4 | 0 | 7 | 2 | 13 | 88 |
| 13 | 32,2154 | 4210 | 4 | 3,15 | 0 | 0 | 1 | 1 | 0 | 0 | 8 | 12 | 20 | 0 | 0 | 0 | 6 | 0 | 0 | 6 | 10 | 2 | 0 | 12 | 4 | 5 | 10 | 0 | 19 | 57 |
| 14 | 214,341 | 5013 | 0 | 839,95 | 0 | 0 | 4 | 4 | 0 | 6 | 5 | 12 | 23 | 0 | 2 | 2 | 12 | 5 | 4 | 21 | 21 | 2 | 0 | 23 | 8 | 5 | 10 | 5 | 28 | 97 |
| 15 | 30,6044 | 5012 | 4 | 163,69 | 1 | 0 | 4 | 4 | 2 | 2 | 6 | 13 | 21 | 0 | 13 | 13 | 25 | 7 | 10 | 42 | 21 | 2 | 0 | 23 | 11 | 10 | 10 | 6 | 37 | 136 |
| 16 | 51,1100 | 1320 | 2 | 60,19 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 13 | 21 | 0 | 0 | 0 | 8 | 0 | 4 | 12 | 0 | 2 | 0 | 2 | 4 | 0 | 0 | 3 | 7 | 42 |
| 17 | 72,5669 | 4110 | 1 | 184,83 | 0 | 0 | 2 | 2 | 0 | 0 | 4 | 13 | 17 | 6 | 7 | 13 | 8 | 9 | 4 | 21 | 21 | 15 | 2 | 38 | 8 | 10 | 12 | 7 | 37 | 126 |
| 18 | 115,3200 | 4110 | 3 | 540,6 | 0 | 0 | 2 | 2 | 1 | 0 | 8 | 8 | 16 | 19 | 0 | 19 | 14 | 4 | 10 | 28 | 21 | 2 | 0 | 23 | 8 | 10 | 12 | 7 | 37 | 123 |
| 19 | 309,6085 | 1330 | 2 | 424,72 | 3 | 0 | 2 | 2 | 1 | 0 | 8 | 4 | 12 | 30 | 7 | 37 | 15 | 6 | 8 | 29 | 21 | 7 | 2 | 30 | 15 | 10 | 14 | 5 | 44 | 152 |
| 20 | 21,4780 | 4110 | 3 | 122,28 | 1 | 0 | 2 | 2 | 1 | 0 | 4 | 14 | 18 | 7 | 7 | 14 | 14 | 1 | 6 | 21 | 14 | 15 | 0 | 29 | 8 | 10 | 10 | 4 | 32 | 114 |
| 21 | 43,4700 | 4110 | 1 | 164,79 | 0 | 0 | 2 | 2 | 0 | 0 | 8 | 6 | 14 | 0 | 0 | 0 | 8 | 0 | 2 | 10 | 11 | 2 | 0 | 13 | 4 | 0 | 13 | 0 | 17 | 54 |
| 22 | 163,7160 | 1320 | 3 | 190,65 | 1 | 0 | 0 | 0 | 1 | 0 | 8 | 12 | 20 | 9 | 12 | 21 | 13 | 4 | 6 | 23 | 19 | 2 | 0 | 21 | 4 | 10 | 6 | 7 | 27 | 112 |
| 23 | 50,6861 | 1330 | 1 | 58,00 | 2 | 0 | 0 | 0 | 2 | 0 | 9 | 17 | 26 | 17 | 15 | 32 | 12 | 6 | 2 | 20 | 0 | 12 | 0 | 12 | 8 | 10 | 0 | 8 | 26 | 116 |
| 24 | 48,6600 | 4110 | 2 | 297,95 | 2 | 0 | 2 | 2 | 1 | 0 | 8 | 13 | 21 | 16 | 10 | 26 | 14 | 7 | 10 | 31 | 22 | 7 | 2 | 31 | 8 | 10 | 14 | 6 | 38 | 147 |
| 25 | 64,9100 | 4110 | 1 | 223,80 | 1 | 0 | 2 | 2 | 1 | 0 | 8 | 9 | 17 | 11 | 0 | 11 | 14 | 5 | 4 | 23 | 16 | 7 | 6 | 29 | 4 | 5 | 12 | 5 | 26 | 106 |
| 26 | 52,4800 | 1320 | 2 | 67,65 | 1 | 0 | 0 | 0 | 1 | 0 | 8 | 8 | 16 | 8 | 0 | 8 | 7 | 0 | 2 | 9 | 0 | 15 | 0 | 15 | 4 | 5 | 0 | 6 | 15 | 63 |
| 27 | 70,0100 | 1320 | 3 | 98,37 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 16 | 0 | 5 | 5 | 8 | 7 | 8 | 23 | 0 | 2 | 0 | 2 | 4 | 10 | 5 | 6 | 25 | 71 |
| 28 | 63,9800 | 4110 | 2 | 477,23 | 1 | 1 | 2 | 2 | 2 | 15 | 9 | 12 | 36 | 28 | 15 | 43 | 25 | 6 | 4 | 35 | 22 | 12 | 4 | 38 | 4 | 10 | 12 | 7 | 33 | 185 |
| 29 | 32,0370 | 1443 | 1 | 18,49 | 3 | 1 | 3 | 6 | 2 | 20 | 9 | 18 | 47 | 30 | 20 | 50 | 25 | 6 | 10 | 41 | 22 | 12 | 8 | 42 | 15 | 10 | 8 | 7 | 40 | 220 |
| 30 | 66,8200 | 1320 | 3 | 80,09 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 8 | 12 | 0 | 0 | 0 | 8 | 2 | 2 | 12 | 0 | 7 | 0 | 7 | 4 | 0 | 0 | 2 | 6 | 37 |
| 31 | 45,9200 | 1320 | 2 | 82,66 | 1 | 0 | 3 | 6 | 1 | 0 | 8 | 12 | 20 | 21 | 5 | 26 | 20 | 4 | 10 | 34 | 16 | 7 | 4 | 27 | 8 | 10 | 5 | 7 | 30 | 137 |
| 32 | 2,2700 | 1430 | 1 | 13,77 | 0 | 1 | 0 | 8 | 0 | 20 | 8 | 14 | 42 | 0 | 0 | 0 | 8 | 11 | 10 | 29 | 0 | 5 | 0 | 5 | 11 | 5 | 1 | 8 | 25 | 101 |
| 33 | 6,0000 | 6040 | 1 | 0,00 | 1 | 1 | 0 | 8 | 1 | 20 | 8 | 6 | 34 | 30 | 0 | 30 | 11 | 12 | 4 | 27 | 0 | 12 | 6 | 18 | 15 | 5 | 1 | 8 | 29 | 138 |
| 34 | 54,0400 | 1320 | 2 | 62,66 | 0 | 0 | 0 | 0 | 1 | 0 | 8 | 4 | 12 | 7 | 3 | 10 | 9 | 6 | 8 | 23 | 0 | 7 | 0 | 7 | 4 | 10 | 0 | 6 | 20 | 72 |
| 35 | 86,1900 | 1330 | 3 | 105,77 | 0 | 0 | 0 | 0 | 1 | 0 | 8 | 12 | 20 | 9 | 2 | 11 | 5 | 0 | 0 | 5 | 0 | 7 | 2 | 9 | 4 | 5 | 1 | 0 | 10 | 55 |
| 36 | 56,5500 | 1310 | 3 | 84,69 | 2 | 1 | 4 | 4 | 1 | 20 | 8 | 17 | 45 | 30 | 5 | 35 | 17 | 3 | 4 | 24 | 22 | 7 | 4 | 33 | 8 | 10 | 11 | 7 | 36 | 173 |
| 37 | 45,4600 | 1310 | 4 | 57,00 | 2 | 0 | 1 | 6 | 2 | 0 | 11 | 16 | 27 | 30 | 15 | 45 | 25 | 6 | 10 | 41 | 16 | 15 | 2 | 33 | 11 | 10 | 6 | 6 | 33 | 179 |
| 38 | 6,4200 | 1310 | 1 | 17,61 | 0 | 0 | 0 | 9 | 2 | 0 | 8 | 18 | 26 | 0 | 5 | 5 | 11 | 7 | 6 | 24 | 2 | 7 | 0 | 9 | 4 | 10 | 11 | 3 | 28 | 92 |
| 39 | 115,2400 | 4110 | 1 | 210,50 | 1 | 0 | 2 | 2 | 1 | 0 | 8 | 12 | 20 | 16 | 3 | 19 | 17 | 3 | 10 | 30 | 18 | 7 | 2 | 27 | 8 | 10 | 13 | 5 | 36 | 132 |
| 40 | 156,8776 | 1320 | 2 | 169,16 | 1 | 0 | 0 | 0 | 1 | 0 | 8 | 12 | 20 | 26 | 5 | 31 | 7 | 4 | 10 | 21 | 0 | 12 | 2 | 14 | 4 | 10 | 0 | 6 | 20 | 106 |
| 41 | 34,6000 | 1310 | 1 | 36,67 | 1 | 0 | 1 | 1 | 2 | 0 | 8 | 14 | 22 | 5 | 15 | 20 | 11 | 3 | 6 | 20 | 14 | 12 | 4 | 30 | 7 | 10 | 10 | 6 | 33 | 125 |
| 42 | 15,0600 | 1310 | 1 | 15,43 | 0 | 0 | 5 | 5 | 1 | 0 | 8 | 7 | 15 | 15 | 7 | 22 | 17 | 4 | 4 | 25 | 16 | 2 | 2 | 20 | 4 | 10 | 8 | 5 | 27 | 109 |
| 43 | 20,1300 | 6020 | 2 | 279,48 | 1 | 0 | 0 | 9 | 2 | 0 | 8 | 17 | 25 | 12 | 10 | 22 | 20 | 7 | 10 | 37 | 0 | 7 | 0 | 7 | 4 | 10 | 1 | 7 | 22 | 113 |
| 44 | 404,4200 | 4110 | 0 | 1383,68 | 1 | 1 | 2 | 2 | 2 | 14 | 8 | 12 | 34 | 19 | 7 | 26 | 25 | 7 | 10 | 42 | 22 | 12 | 0 | 34 | 8 | 10 | 15 | 6 | 39 | 175 |
| 45 | 18,3236 | 1310 | 1 | 26,80 | 0 | 0 | 0 | 8 | 1 | 0 | 9 | 14 | 23 | 14 | 0 | 14 | 25 | 7 | 6 | 38 | 0 | 0 | 0 | 0 | 15 | 5 | 1 | 4 | 25 | 100 |
| 46 | 36,6200 | 6050 | 1 | 84,17 | 0 | 0 | 0 | 8 | 1 | 0 | 8 | 16 | 24 | 20 | 0 | 20 | 14 | 3 | 4 | 21 | 0 | 5 | 0 | 5 | 15 | 5 | 1 | 4 | 25 | 95 |
| 47 | 5,0000 | 8231 | 2 | 5,95 | 0 | 0 | 0 | 7 | 1 | 4 | 4 | 13 | 21 | 9 | 3 | 12 | 14 | 4 | 10 | 28 | 1 | 7 | 0 | 8 | 8 | 5 | 0 | 7 | 20 | 89 |
| 48 | 94,2100 | 1443 | 4 | 365,47 | 0 | 0 | 3 | 3 | 1 | 0 | 0 | 11 | 11 | 19 | 3 | 22 | 25 | 8 | 4 | 37 | 14 | 2 | 0 | 16 | 0 | 5 | 7 | 1 | 13 | 99 |
| 49 | 119,9100 | 4120 | 4 | 377,95 | 0 | 0 | 2 | 2 | 0 | 0 | 8 | 13 | 21 | 0 | 0 | 0 | 6 | 2 | 2 | 10 | 16 | 2 | 0 | 18 | 4 | 0 | 15 | 4 | 23 | 72 |
| 50 | 76,8122 | 4120 | 2 | 266,12 | 2 | 0 | 2 | 2 | 1 | 0 | 8 | 13 | 21 | 26 | 7 | 33 | 23 | 8 | 6 | 37 | 18 | 15 | 2 | 35 | 8 | 10 | 9 | 5 | 32 | 158 |

*Appendix C: Economic pillar, scores*

| ID_farm | UAA | OTE | GEO | SO | BRAND | ORG | LIVES | I_P | MULTI | 34_a | 34_b | 34 | 35_a | 35_b | 35 | ECO_1 | 36_a | 36 | 37_a | 37 | ECO_2 | 38_a | 38 | 39_a | 39 | ECO_3 | 40_a | 40_b | 40_c | 40 | 41_a | 41_b | 41 | ECO_4 | 42_a | 42 | ECO_5 | TOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 31,4801 | 4110 | 1 | 94,59 | 1 | 1 | 2 | 2 | 2 | 14 | 9 | 23 | 3 | 11 | 14 | 37 | 9 | 9 | 18 | 18 | 27 | 19 | 19 | 25 | 25 | 44 | 2 | 6 | 6 | 14 | 4 | 3 | 7 | 21 | 14 | 14 | 14 | 143 |
| 2 | 85,1500 | 1320 | 2 | 101,48 | 0 | 0 | 0 | 0 | 0 | 10 | 12 | 22 | 2 | 15 | 17 | 39 | 13 | 13 | 25 | 25 | 38 | 18 | 18 | 20 | 20 | 38 | 3 | 1 | 4 | 8 | 4 | 0 | 4 | 12 | 0 | 0 | 0 | 127 |
| 3 | 40,1083 | 1330 | 3 | 42,82 | 2 | 1 | 1 | 1 | 2 | 13 | 8 | 21 | 4 | 12 | 16 | 37 | 12 | 12 | 18 | 18 | 30 | 21 | 21 | 17 | 17 | 38 | 2 | 10 | 5 | 17 | 10 | 10 | 20 | 37 | 42 | 42 | 42 | 184 |
| 4 | 73,4676 | 1320 | 2 | 87,46 | 0 | 0 | 0 | 0 | 0 | 11 | 10 | 21 | 3 | 15 | 18 | 39 | 16 | 16 | 23 | 23 | 39 | 19 | 19 | 21 | 21 | 40 | 1 | 1 | 7 | 9 | 4 | 0 | 4 | 13 | 6 | 6 | 6 | 137 |
| 5 | 94,8276 | 4110 | 1 | 345,72 | 0 | 0 | 2 | 2 | 0 | 13 | 11 | 24 | 3 | 15 | 18 | 42 | 10 | 10 | 25 | 25 | 35 | 20 | 20 | 23 | 23 | 43 | 3 | 0 | 6 | 9 | 3 | 0 | 3 | 12 | 0 | 0 | 0 | 132 |
| 6 | 122,683 | 8120 | 4 | 147,45 | 0 | 0 | 2 | 2 | 1 | 7 | 7 | 14 | 0 | 5 | 5 | 19 | 0 | 0 | 0 | 0 | 0 | 25 | 25 | 19 | 19 | 44 | 6 | 3 | 7 | 16 | 6 | 2 | 8 | 24 | 5 | 5 | 5 | 92 |
| 7 | 1,4400 | 1310 | 1 | 1,13 | 0 | 1 | 0 | 8 | 0 | 15 | 3 | 18 | 6 | 6 | 12 | 30 | 19 | 19 | 9 | 9 | 28 | 24 | 24 | 0 | 0 | 24 | 1 | 0 | 10 | 11 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 93 |
| 8 | 60,0000 | 1443 | 3 | 66,70 | 1 | 0 | 3 | 3 | 1 | 10 | 10 | 20 | 3 | 15 | 18 | 38 | 18 | 18 | 24 | 24 | 42 | 23 | 23 | 25 | 25 | 48 | 4 | 2 | 6 | 12 | 7 | 3 | 10 | 22 | 26 | 26 | 26 | 176 |
| 9 | 53,5675 | 8130 | 1 | 92,44 | 0 | 0 | 1 | 1 | 0 | 10 | 9 | 19 | 1 | 12 | 13 | 32 | 9 | 9 | 20 | 20 | 29 | 19 | 19 | 19 | 19 | 38 | 1 | 1 | 6 | 8 | 1 | 0 | 1 | 9 | 2 | 2 | 2 | 110 |
| 10 | 33,2173 | 1320 | 3 | 39,36 | 0 | 0 | 0 | 0 | 1 | 10 | 12 | 22 | 2 | 15 | 17 | 39 | 14 | 14 | 25 | 25 | 39 | 18 | 18 | 25 | 25 | 43 | 2 | 1 | 5 | 8 | 7 | 2 | 9 | 17 | 5 | 5 | 5 | 143 |
| 11 | 13,1290 | 8130 | 1 | 13,20 | 0 | 0 | 1 | 1 | 0 | 8 | 4 | 12 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 25 | 25 | 25 | 25 | 50 | 3 | 0 | 7 | 10 | 8 | 0 | 8 | 18 | 0 | 0 | 0 | 80 |
| 12 | 6,1282 | 5013 | 1 | 22,16 | 0 | 0 | 1 | 6 | 1 | 15 | 6 | 21 | 6 | 9 | 15 | 36 | 16 | 16 | 13 | 13 | 29 | 24 | 24 | 18 | 18 | 42 | 4 | 1 | 2 | 7 | 10 | 10 | 20 | 27 | 49 | 49 | 49 | 183 |
| 13 | 32,2154 | 4210 | 4 | 3,15 | 0 | 0 | 1 | 1 | 0 | 5 | 6 | 11 | 0 | 2 | 2 | 13 | 2 | 2 | 4 | 4 | 6 | 23 | 23 | 25 | 25 | 48 | 2 | 0 | 8 | 10 | 8 | 0 | 8 | 18 | 0 | 0 | 0 | 85 |
| 14 | 214,341 | 5013 | 0 | 839,95 | 0 | 0 | 4 | 4 | 0 | 15 | 15 | 25 | 3 | 15 | 18 | 43 | 5 | 5 | 25 | 25 | 30 | 21 | 21 | 24 | 24 | 45 | 2 | 2 | 4 | 8 | 7 | 0 | 7 | 15 | 0 | 0 | 0 | 133 |
| 15 | 30,6044 | 5012 | 4 | 163,69 | 1 | 0 | 4 | 4 | 2 | 15 | 10 | 25 | 6 | 15 | 21 | 46 | 12 | 12 | 22 | 22 | 34 | 24 | 24 | 25 | 25 | 49 | 1 | 3 | 7 | 11 | 8 | 0 | 8 | 19 | 48 | 48 | 48 | 196 |
| 16 | 51,1100 | 1320 | 2 | 60,19 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 20 | 2 | 15 | 17 | 37 | 15 | 15 | 25 | 25 | 40 | 18 | 18 | 25 | 25 | 43 | 2 | 0 | 6 | 8 | 5 | 0 | 5 | 13 | 0 | 0 | 0 | 133 |
| 17 | 72,5669 | 4110 | 1 | 184,83 | 0 | 0 | 2 | 2 | 0 | 11 | 10 | 21 | 3 | 15 | 18 | 39 | 17 | 17 | 23 | 23 | 40 | 22 | 22 | 22 | 22 | 44 | 3 | 2 | 6 | 11 | 4 | 2 | 6 | 17 | 10 | 10 | 10 | 150 |
| 18 | 115,3200 | 4110 | 3 | 540,60 | 0 | 0 | 2 | 2 | 1 | 8 | 8 | 16 | 0 | 7 | 7 | 23 | 6 | 6 | 16 | 16 | 22 | 14 | 14 | 25 | 25 | 39 | 4 | 3 | 7 | 14 | 5 | 1 | 6 | 20 | 1 | 1 | 1 | 105 |
| 19 | 309,6085 | 1330 | 2 | 424,72 | 3 | 0 | 2 | 2 | 1 | 10 | 12 | 22 | 2 | 15 | 17 | 39 | 16 | 16 | 25 | 25 | 41 | 19 | 19 | 22 | 22 | 41 | 4 | 8 | 5 | 17 | 6 | 1 | 7 | 24 | 4 | 4 | 4 | 149 |
| 20 | 21,4780 | 4110 | 3 | 122,28 | 1 | 0 | 2 | 2 | 1 | 15 | 10 | 25 | 5 | 14 | 19 | 44 | 12 | 12 | 22 | 22 | 34 | 21 | 21 | 25 | 25 | 46 | 3 | 5 | 3 | 11 | 2 | 0 | 2 | 13 | 0 | 0 | 0 | 137 |
| 21 | 43,4700 | 4110 | 1 | 164,79 | 0 | 0 | 2 | 2 | 0 | 14 | 13 | 25 | 4 | 15 | 19 | 44 | 13 | 13 | 25 | 25 | 38 | 22 | 22 | 24 | 24 | 46 | 2 | 0 | 7 | 9 | 2 | 0 | 2 | 11 | 0 | 0 | 0 | 139 |
| 22 | 163,7160 | 1320 | 3 | 190,65 | 1 | 0 | 0 | 0 | 1 | 10 | 14 | 24 | 3 | 15 | 18 | 42 | 16 | 16 | 25 | 25 | 41 | 20 | 20 | 24 | 24 | 44 | 4 | 6 | 4 | 14 | 7 | 3 | 10 | 24 | 10 | 10 | 10 | 161 |
| 23 | 50,6861 | 1330 | 1 | 58,00 | 2 | 0 | 0 | 0 | 2 | 10 | 11 | 21 | 2 | 15 | 17 | 38 | 13 | 13 | 25 | 25 | 38 | 19 | 19 | 22 | 22 | 41 | 2 | 8 | 8 | 18 | 8 | 1 | 9 | 27 | 18 | 18 | 18 | 162 |
| 24 | 48,6600 | 4110 | 2 | 297,95 | 2 | 0 | 2 | 2 | 1 | 15 | 11 | 25 | 6 | 15 | 21 | 46 | 15 | 15 | 24 | 24 | 39 | 21 | 21 | 22 | 22 | 43 | 3 | 5 | 5 | 13 | 3 | 2 | 5 | 18 | 8 | 8 | 8 | 154 |
| 25 | 64,9100 | 4110 | 1 | 223,80 | 1 | 0 | 2 | 2 | 1 | 12 | 10 | 22 | 3 | 15 | 18 | 40 | 16 | 16 | 22 | 22 | 38 | 21 | 21 | 25 | 25 | 46 | 3 | 3 | 4 | 10 | 2 | 1 | 3 | 13 | 0 | 0 | 0 | 137 |
| 26 | 52,4800 | 1320 | 2 | 67,65 | 1 | 0 | 0 | 0 | 1 | 10 | 14 | 24 | 2 | 15 | 17 | 41 | 16 | 16 | 25 | 25 | 41 | 18 | 18 | 23 | 23 | 41 | 1 | 2 | 5 | 8 | 5 | 2 | 7 | 15 | 5 | 5 | 5 | 143 |
| 27 | 70,0100 | 1320 | 3 | 98,37 | 0 | 0 | 0 | 0 | 0 | 10 | 9 | 19 | 3 | 14 | 17 | 36 | 16 | 16 | 23 | 23 | 39 | 18 | 18 | 23 | 23 | 41 | 3 | 1 | 4 | 8 | 5 | 0 | 5 | 13 | 0 | 0 | 0 | 129 |
| 28 | 63,9800 | 4110 | 2 | 477,23 | 1 | 1 | 2 | 2 | 2 | 15 | 12 | 25 | 8 | 15 | 23 | 48 | 17 | 17 | 25 | 25 | 42 | 22 | 22 | 23 | 23 | 45 | 4 | 6 | 5 | 15 | 4 | 2 | 6 | 21 | 12 | 12 | 12 | 168 |
| 29 | 32,0370 | 1443 | 1 | 18,49 | 3 | 1 | 3 | 6 | 2 | 10 | 5 | 15 | 2 | 9 | 11 | 26 | 1 | 1 | 9 | 9 | 10 | 11 | 11 | 25 | 25 | 36 | 7 | 7 | 4 | 18 | 10 | 4 | 14 | 32 | 39 | 39 | 39 | 143 |
| 30 | 66,8200 | 1320 | 3 | 80,09 | 0 | 0 | 0 | 0 | 0 | 10 | 9 | 19 | 2 | 14 | 16 | 35 | 16 | 16 | 23 | 23 | 39 | 18 | 18 | 25 | 25 | 43 | 2 | 0 | 7 | 9 | 7 | 0 | 7 | 16 | 0 | 0 | 0 | 133 |
| 31 | 45,9200 | 1320 | 2 | 82,66 | 1 | 0 | 3 | 6 | 1 | 11 | 10 | 21 | 2 | 14 | 16 | 37 | 12 | 12 | 21 | 21 | 33 | 17 | 17 | 23 | 23 | 40 | 6 | 4 | 4 | 14 | 5 | 2 | 7 | 21 | 5 | 5 | 5 | 136 |
| 32 | 2,2700 | 1430 | 1 | 13,77 | 0 | 1 | 0 | 8 | 0 | 15 | 3 | 18 | 5 | 5 | 10 | 28 | 14 | 14 | 7 | 7 | 21 | 24 | 24 | 25 | 25 | 49 | 3 | 0 | 6 | 9 | 3 | 0 | 3 | 12 | 12 | 12 | 12 | 122 |
| 33 | 6,0000 | 6040 | 1 | 0,00 | 1 | 1 | 0 | 8 | 1 | 7 | 2 | 9 | 0 | 4 | 4 | 13 | 5 | 5 | 3 | 3 | 8 | 14 | 14 | 25 | 25 | 39 | 3 | 3 | 7 | 13 | 10 | 10 | 20 | 33 | 43 | 43 | 43 | 136 |
| 34 | 54,0400 | 1320 | 2 | 62,66 | 0 | 0 | 0 | 0 | 1 | 10 | 11 | 21 | 2 | 15 | 17 | 38 | 14 | 14 | 25 | 25 | 39 | 18 | 18 | 25 | 25 | 43 | 1 | 3 | 4 | 8 | 6 | 2 | 8 | 16 | 6 | 6 | 6 | 142 |
| 35 | 86,1900 | 1330 | 3 | 105,77 | 0 | 0 | 0 | 0 | 1 | 7 | 13 | 20 | 0 | 9 | 9 | 29 | 2 | 2 | 22 | 22 | 24 | 9 | 9 | 25 | 25 | 34 | 4 | 2 | 7 | 13 | 7 | 1 | 8 | 21 | 4 | 4 | 4 | 112 |
| 36 | 56,5500 | 1310 | 3 | 84,69 | 2 | 1 | 4 | 4 | 1 | 8 | 5 | 13 | 0 | 6 | 6 | 19 | 3 | 3 | 10 | 10 | 13 | 13 | 13 | 25 | 25 | 38 | 5 | 5 | 6 | 16 | 5 | 2 | 7 | 23 | 12 | 12 | 12 | 105 |
| 37 | 45,4600 | 1310 | 4 | 57,00 | 2 | 0 | 1 | 6 | 2 | 12 | 7 | 19 | 4 | 12 | 16 | 35 | 13 | 13 | 18 | 18 | 31 | 22 | 22 | 15 | 15 | 37 | 10 | 7 | 5 | 22 | 10 | 10 | 20 | 42 | 46 | 46 | 46 | 191 |
| 38 | 6,4200 | 1310 | 1 | 17,61 | 0 | 0 | 0 | 9 | 2 | 11 | 2 | 13 | 0 | 1 | 1 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 25 | 25 | 2 | 1 | 4 | 7 | 4 | 0 | 4 | 11 | 45 | 45 | 45 | 95 |
| 39 | 115,2400 | 4110 | 1 | 210,50 | 1 | 0 | 2 | 2 | 1 | 12 | 11 | 23 | 5 | 15 | 20 | 43 | 20 | 20 | 25 | 25 | 45 | 23 | 23 | 18 | 18 | 41 | 4 | 4 | 6 | 14 | 5 | 4 | 9 | 23 | 16 | 16 | 16 | 168 |
| 40 | 156,8776 | 1320 | 2 | 169,16 | 1 | 0 | 0 | 0 | 1 | 10 | 15 | 25 | 3 | 15 | 18 | 43 | 17 | 17 | 25 | 25 | 42 | 19 | 19 | 20 | 20 | 39 | 2 | 6 | 6 | 14 | 7 | 3 | 10 | 24 | 10 | 10 | 10 | 158 |
| 41 | 34,6000 | 1310 | 1 | 36,67 | 1 | 0 | 1 | 1 | 2 | 10 | 9 | 19 | 0 | 6 | 6 | 25 | 3 | 3 | 15 | 15 | 18 | 13 | 13 | 25 | 25 | 38 | 3 | 5 | 8 | 16 | 7 | 4 | 11 | 27 | 28 | 28 | 28 | 136 |
| 42 | 15,0600 | 1310 | 1 | 15,43 | 0 | 0 | 5 | 5 | 1 | 15 | 8 | 23 | 8 | 14 | 22 | 45 | 21 | 21 | 22 | 22 | 43 | 20 | 20 | 24 | 24 | 44 | 3 | 3 | 7 | 13 | 6 | 4 | 10 | 23 | 21 | 21 | 21 | 176 |
| 43 | 20,1300 | 6020 | 2 | 279,48 | 1 | 0 | 0 | 9 | 2 | 15 | 9 | 24 | 6 | 14 | 20 | 44 | 12 | 12 | 21 | 21 | 33 | 23 | 23 | 14 | 14 | 37 | 3 | 2 | 5 | 10 | 9 | 3 | 12 | 22 | 38 | 38 | 38 | 174 |
| 44 | 404,4200 | 4110 | 0 | 1383,68 | 1 | 1 | 2 | 2 | 2 | 13 | 12 | 25 | 2 | 14 | 16 | 41 | 7 | 7 | 25 | 25 | 32 | 22 | 22 | 24 | 24 | 46 | 4 | 8 | 4 | 16 | 3 | 2 | 5 | 21 | 5 | 5 | 5 | 145 |
| 45 | 18,3236 | 1310 | 1 | 26,80 | 0 | 0 | 0 | 8 | 1 | 15 | 7 | 22 | 9 | 10 | 19 | 41 | 8 | 8 | 18 | 18 | 26 | 25 | 25 | 3 | 3 | 28 | 3 | 1 | 2 | 6 | 1 | 1 | 2 | 8 | 50 | 50 | 50 | 153 |
| 46 | 36,6200 | 6050 | 1 | 84,17 | 0 | 0 | 0 | 8 | 1 | 10 | 8 | 18 | 3 | 13 | 16 | 34 | 12 | 12 | 22 | 22 | 34 | 21 | 21 | 25 | 25 | 46 | 3 | 2 | 8 | 13 | 6 | 4 | 10 | 23 | 13 | 13 | 13 | 150 |
| 47 | 5,0000 | 8231 | 2 | 5,95 | 0 | 0 | 0 | 7 | 1 | 15 | 4 | 19 | 7 | 9 | 16 | 35 | 21 | 21 | 15 | 15 | 36 | 25 | 25 | 25 | 25 | 50 | 2 | 4 | 3 | 9 | 7 | 5 | 12 | 21 | 50 | 50 | 50 | 192 |
| 48 | 94,2100 | 1443 | 4 | 365,47 | 0 | 0 | 3 | 3 | 1 | 13 | 8 | 21 | 5 | 14 | 19 | 40 | 8 | 8 | 25 | 25 | 33 | 23 | 23 | 19 | 19 | 42 | 2 | 3 | 7 | 12 | 6 | 2 | 8 | 20 | 14 | 14 | 14 | 149 |
| 49 | 119,9100 | 4120 | 4 | 377,95 | 0 | 0 | 2 | 2 | 0 | 11 | 14 | 25 | 2 | 15 | 17 | 42 | 13 | 13 | 25 | 25 | 38 | 21 | 21 | 24 | 24 | 45 | 4 | 0 | 5 | 9 | 2 | 0 | 2 | 11 | 0 | 0 | 0 | 136 |
| 50 | 76,8122 | 4120 | 2 | 266,12 | 2 | 0 | 2 | 2 | 1 | 14 | 11 | 25 | 3 | 14 | 17 | 42 | 8 | 8 | 25 | 25 | 33 | 19 | 19 | 19 | 19 | 38 | 4 | 8 | 5 | 17 | 4 | 2 | 6 | 23 | 8 | 8 | 8 | 144 |