

AESIS: a support tool for the evaluation of sustainability of agroecosystems. Example of applications to organic and integrated farming systems in Tuscany, Italy

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Abstract

Agricultural researchers widely recognise the importance of sustainable agricultural production systems and the need to develop appropriate methods to measure sustainability on the farm level. Policy makers need accounting and evaluation tools to be able to assess the potential of sustainable production practices and to provide appropriate agro-environmental policy measures. Farmers are in search of sustainable management tools to cope with regulations and enhance efficiency. This paper presents the outcomes of applications to organic and integrated farming of an indicator-based framework to evaluate sustainability of farming systems (Agro-Environmental Sustainability Information System, AESIS). The AESIS was described together with a review of applications dating from 1991 in a previous paper. The objective of the present paper is to present the AESIS application to organic and integrated farming systems in Val d'Elsa (Tuscany) and discuss how it is adapted for application to ordinary farms. The AESIS is organised into a number of environmental and

production systems. For each system, environmental critical points are identified with corresponding agro-environmental indicators and processing methods. Possible solutions to sustainability issues and critical points of relevance to the agricultural sector of the local economic and agro-ecological zone are formulated by including an experimental layout, identifying indicator thresholds and by defining management systems with corresponding policy measures. Alternative solutions are evaluated by calculating and measuring the relevant indicators.

The outcomes of the AESIS applications are discussed with specific relevance to the operational adoptability of AESIS to ordinary, agri-touristic farms managed with the organic and the integrated production method, respectively. The AESIS framework proved to be sufficiently flexible to meet the requirements for ordinary farm applications while keeping a holistic perspective and considering pedo-climatic and production factors on different spatial scales.

Introduction

Indicators are often used to measure sustainability performance on different spatial scales: these indicators may either be strongly ecological in focus and very detailed, or they may be more policy-oriented. Therefore, indicators have been developed that differ greatly in information content and in the degree of condensation of this information (Braat, 1991). In order to guide decision-makers in taking coherent choices based on the sustainability principles, indicators can be embedded in a logical sequence of phases, often called *framework*.

Currently, there is a vast range of indicator-based frameworks to evaluate sustainability of both farming systems (FSs) and land-use. Some focus on environmental impact (for an example, see the critical review of 12 indicator-based methods reported by Van der Werf and Petit, 2002), whilst others hold a stronger holistic component and also consider socio-economic aspects. Examples of the latter type of frameworks, broadly applied in the agricultural sector, include the International Framework for Evaluating Sustainable Land Management (FESLM, Smith and Dumanski, 1994), the framework of the Research Network on Integrated and Ecological Arable Farming Systems for EU and Associated Countries (Vereijken, 1999), the Checklist for Sustainable Landscape Management (Van Mansvelt and Van der Lubbe, 1999), the Problem-Solving Framework for Modelling Sustainability Issues (Weersink *et al.*, 2002) and the Framework for Assessing the Sustainability of Natural Resource Management Systems (MESMIS, López-Ridaura *et al.*, 2002).

In general, the above-mentioned frameworks are based on a strong conceptual background with a complex organisation of the evaluation protocols. However, due to either cryptic theoretical superstructures or to a narrow range of application purposes, their direct practical applicability to ordinary farms is questionable. For the purpose of this paper,

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an ordinary farm is defined as a farm that is not a model or an experimental farm, i.e. a common farm. For more details on the differences between an experimental and an ordinary farm, reference is made to Lewis (1836). More research effort is required to optimise the balance between conceptual soundness and operationality. Besides, indicators currently used often lack reference to different hierarchical spatial levels and do not consider pedo-climatic variability.

In a previous paper, an indicator-based framework to evaluate sustainability of farming systems was presented together with a review of its applications dating from 1991 (Pacini *et al.*, 2009). The framework, entitled Agro-Environmental Sustainability Information System (AESIS), is a holistically designed information system to support decisions at different levels in the agricultural sector.

The AESIS (current formulation of the framework) and its previous version (the EAIS, environmental accounting information system; Pacini *et al.*, 2000; Pacini *et al.*, 2003) have been developed since 1991 from previous experiences (Pileri, 1992; Vazzana *et al.*, 1997; Vereijken, 1999) aimed at finding the right balance between a range of different application purposes and the level of complexity of indicators, including different spatial scales, production and pedo-climatic factors. During this time span, the framework has been developed through the incorporation of new elements, including those retrieved from the above-mentioned studies. To our knowledge, in the literature of indicator-based frameworks for farm evaluation of sustainability, there are no examples of applications comparing integrated and organic, vine-olive production oriented FSs.

In this paper, the application of AESIS to two ordinary farms conducted with the organic and the integrated farming method, respectively, is presented in detail. The two farms are oriented towards vine and olive production and are representative of relevant production systems under the organic and the integrated methods in Val d'Elsa, Tuscany.

In previous publications, the application of AESIS for modelling decisions of integrated ecological-economic farm management was presented (Pacini *et al.*, 2003; Pacini *et al.*, 2004a; Pacini *et al.*, 2004b). In the present paper, the adaptation of AESIS for the application to ordinary farms is discussed. Concerning adaptation of AESIS for ordinary farm applications, the challenge of this paper is to reveal the didactic power of AESIS; under this perspective the focus of the present article is not on indicator methods and calculations but on the AESIS logical sequence of phases and how they should be interpreted to facilitate the process of sustainability evaluation when large samples of ordinary farms are involved. The two farms presented are used as examples for the application of the complete sequence of AESIS phases, while results of indicators should be interpreted considering the limitations due to such a small sample.

Materials and Methods

Farms and sites

The AESIS was applied to two ordinary farms located in Val d'Elsa, an area about 40 km southwest of Florence in Central Tuscany (latitude 44°N) that focuses primarily on vine production. The climate of Val d'Elsa is Mediterranean, with an average annual rainfall of 650 mm. Although a high quality production is a standard practice in Val d'Elsa, large parts of this sub-region are still excluded from the richest Tuscan wine markets, which give even more importance to alternative, multi-functional activities such as agritourism.

As indicated by the report of the regional Tuscan environmental action plan (Regione Toscana, 2003), the quality of the environment in Val d'Elsa is higher than the regional average, which supports the development of agritourism. However, such high standards of quality must be kept in close relationship with sustainable farming practices.

In order to obtain outcomes of practical use for the entire Val d'Elsa area, while maintaining a high resolution of the analysis, two farms were selected as representative of production systems under organic and integrated production according to the following criteria: i) Farmlands with the soil types, land morphology, and hydrological conditions characteristic of the area; ii) farms with a land use similar to the average area of those local farms employing at least one full time worker (ISTAT, 2000). La Sorbigliana is an organic farm located in the municipality of Castelfiorentino that has vineyards, olive trees, and a rotation of arable crops. In 2001, the farm started following organic management techniques in accordance with the EU Regulation 2092/91. La Sorbigliana has a total land area of 38.90 ha, cultivates 2.31 ha of vineyards, 4.83 ha of olive trees, 18.04 ha of arable crops, 4.82 ha of fallow and unproductive land, and 8.90 ha of woodland.

Poggio ai Grilli, located in the municipality of Gambassi Terme, is an integrated farm that cultivates fruit and grain in addition to vineyards and olive trees. It follows integrated production rules, as defined by the corresponding agri-environmental measure of the 2000-2006 Tuscany rural development plan. Of the farm's 19.58 ha, vineyards are cultivated on 9.73 ha, olive trees on 0.30 ha, corn on 3.60 ha, and a variety of fruit trees (pear, apple, peach, plum, and apricot) on 0.83 ha.

Organic agriculture is supported by a holistic approach, which is not present in integrated agriculture as it is performed today. Moreover, in organic farming the use of synthetic agrochemicals is strictly forbidden, while integrated farming rules allow the application of synthetic fertilizers as well as of synthetic pesticides subject to a threshold criterion.

To perform a detailed spatial scale analysis, each farm was divided into several different sites according to land morphology and soil conditions (Table 1). Under the AESIS framework a site is defined as a farm spatial sub-unit having relatively homogeneous slopes, soil types, water table and climate. Within a site, there could be one or more crops. Data for the AESIS application were collected on farm, site and site-representative fields of each crop.

The AESIS approach

An in-depth description of AESIS is given in Pacini *et al.* (2009). Here, the AESIS procedural phases are summarized with the aim to recall the AESIS general features and show how it can be applied to ordinary farms. The main feature of the indicator framework is the importance given to different spatial scales (farm, site and field), to the production and pedo-climatic factors, and to the holistic view of the agro-ecosystem.

The framework has been developed to undertake different tasks ranging from modelling approaches, to long-term experiments in experimental stations, to farm-level management systems and policy monitoring. Besides, as explained in Pacini *et al.* (2009), the framework has been designed and tested to be coherent with the current European financial accounting model (FADN; EC, 2009).

The AESIS was aimed at finding the right balance between a range of different application purposes and the level of complexity of indica-

Table 1. Farm and site characteristics and areas.

Farm/site	Land morphology	Soil texture	AAU* (ha)	Total area (ha)
La Sorbigliana			25.18	38.90
Site SRB1	Plain	Sandy clay loam	9.40	13.46
Site SRB2	Hilly	Sandy loam	15.78	19.64
Site SRBwood	Hilly	-	0.00	5.80
Poggio ai Grilli			16.70	19.58
Site PG1	Plain	Loam	12.30	13.62
Site PG2	Hilly	Clay loam	4.40	5.96

*Agricultural area used.

tors. Agro-environmental indicators can be calculated, simulated with models or directly measured with different levels of detail, in proportion to the aims of the evaluation exercise. The procedural phases to apply the framework are reported in Table 2, so as they were modified from Weersink *et al.* (2002), and explained in the following sections.

Phase 1. Definition of the sustainability issues

Being a framework oriented to a problem-solving approach, the AESIS application procedure was initiated with gathering of already available information on the issues related to sustainability in the region (AESIS sub-phase 1.1). Thereafter, specific environmental critical points, that connect issues with the farm agroecosystem, were pinpointed (sub-phase 1.2). The AESIS was organised into several environmental and production systems, as well as their respective subsystems. Within each module, a number of environmental and production processes take place, which, in turn, affect the relevant critical points. A set of agro-environmental indicators for the quantification of the performance of the management of each environmental and production process in the agro-ecosystem was then identified (sub-phase 1.3).

Phase 2. Problem-solving approach to the sustainability issues

The AESIS was developed not only to assess the sustainability of farms but also to evaluate possible production alternatives in order to improve the environmental performances of production processes. The first step of this process consisted of designing a comparison layout where current practices under evaluation were compared with different management systems and with scientifically determined sustainability thresholds (sub-phase 2.1). The thresholds are identified for each single indicator. They are part of the solution to the sustainability problem and determine the extent to which decision-makers change their strategies in order to attain the goals they represent (sub-phase 2.2). In the case of Val d'Elsa the comparison layout included the comparison between integrated and organic agriculture as well as comparisons of the integrated and the organic farming systems (IFS and OFS, respectively) with thresholds.

Thereafter, the management systems indicated in the comparison

layout (i.e., organic and integrated) were described (sub-phase 2.3). The next AESIS step involving the identification of policy measures (sub-phase 2.4) was not enforced, as it applies only to farm modelling studies (Pacini *et al.*, 2009).

Phase 3. Evaluating alternative solutions

In this phase of the evaluation procedure, the calculation methods of the indicators were selected following a criterion of proportionality to the evaluation purpose (sub-phase 3.1). For example, indicator processing methods for policy auditing have to be applied to a large number of farms and as such may be based on simple presence/absence observations, whereas some indicators for research and policy planning are calculated for selected representative farms by applying complex, ecological-environmental models with high data input requirements such as GLEAMS (Knisel, 1993) or CropSYST (Stockle *et al.*, 2003) (for examples of applications of these two models within the AESIS framework, reference is made to Pacini *et al.*, 2003, and Moriondo *et al.*, 2010, respectively). In the two farms under survey we chose to apply a combination of in-field observations and simple simulation modelling. For an application to ordinary farms such as that presented here we discarded any farm integrated modelling exercise (sub-phase 3.2).

Finally, indicators were measured (sub-phase 3.3) and results were presented (sub-phase 3.4). This is particularly important, as the evaluation exercise would be meaningless if the beneficiaries of the information were unable to gain a clear idea of the results of the exercise and the implications on their decisions. A number of possible options exist to show the results. However, as discussed in Pacini *et al.* (2009), trade-off curves and spider diagrams are the most common in indicator framework studies.

Results

In the next sections, the results of the case-study application are presented by following the entire process phase by phase, as reported in Table 2.

Phase 1. Definition of the sustainability issues

The definition of local sustainability issues was initiated from the review of the situation in Val d'Elsa given by the report on the state of the environment in the 2004-2006 Tuscany Regional environmental action plan (Consiglio Regionale della Regione Toscana, 2004, sub-phase 1.1). In the second Annex of the plan, environmental analyses of homogeneous areas (including Val d'Elsa) in Tuscany were summarised by reporting the results of 18 landscape indicators, ranging from agricultural pressure to demographic and production density, tourism intensity, CO₂ emissions, exposition to air pollution, production of wastes and others. Environmental criticality was measured for 16 of these indicators. In the case of Val d'Elsa, the indicator criticality ranged from absent (1 indicator), very low (4), low (10, including % of fertilised agricultural area used, AAU, and % of AAU treated with pesticides) and average (1), as compared to regional averages of Tuscany. In general, Val d'Elsa revealed a very high level of environmental quality combined with an extensive type of agricultural practice.

This data was used to identify sustainability issues in Val d'Elsa. The situation depicted by the above-mentioned indicators on the regional level (i.e., environmental quality and low pressure from agricultural activities) adapt well to multi-functional activities such as agri-tourism: in fact, agri-touristic, family-run farms are common in the area, with many oriented towards vine and olive production. Here a sustainability issue arises on how to combine intensive production sys-

Table 2. AESIS procedural phases (modified from Weersink *et al.*, 2002).

Phase 1. Definition of the sustainability issues

- 1.1. Identify issues related to sustainability in the region
- 1.2. Identify critical points and connect them to farm environmental and production systems
- 1.3. Choose indicators

Phase 2. Problem-solving approach to the sustainability issues

- 2.1. Formulate a comparison layout (e.g., analysis of farm performances with thresholds, comparisons of different management systems/techniques on the same farm, comparisons between farms, comparisons between farm model simulation results)
- 2.2. Identify indicator thresholds (or critical limits, sustainability targets)
- 2.3. Describe the management systems (e.g., organic, integrated, environmentally-friendly, best available technologies etc.) applied in the comparison layout
- 2.4. Identify potential policy measures

Phase 3. Evaluating alternative solutions

- 3.1. Select calculation methods of indicators in proportion to the evaluation purpose
- 3.2. Integrate indicators in a farm simulation model (optional)
- 3.3. Measure indicators
- 3.4. Present and analyze results

tems (especially vine) with the need to guarantee environmental health on the farm level, and more generally on how to maintain the quality of the environment. Hence, the next step consisted of identifying the farm environmental critical points (sub-phase 1.2). Thereafter, corresponding measurable indicators were chosen with special reference to vine production under a systemic approach (sub-phase 1.3).

In columns a, b, c of Table 3, the results of these two steps (sub-phases 1.2 and 1.3) are reported. Starting from the AESIS general framework presented in Pacini *et al.* (2009), critical points were selected from the complete AESIS list coherently with the identified sustainability issue (reported in italics). To maintain a holistic view of the FSs, all farm environmental systems were included in the analysis (italics character). Following the proportionality principle, and considering the scale of family-run, ordinary farms, a minimum of one indicator per environmental system was chosen (italics character). A total of 8 indicators were applied.

Phase 2. Problem-solving approach to the sustainability issues

The second macro-phase of AESIS consisted of finding potential solutions to the conflict *vine intensive production versus promoting*

environmental quality for farm agri-touristic activities and the maintenance of ecological health in Val d'Elsa. First, a comparison layout was settled by choosing two representative farming systems run with organic and integrated management, respectively (sub-phase 2.1). Previous studies focusing on pesticide impact in the area (Lotti *et al.*, 2006), revealed that conventional FSs provoke considerably higher risks than those linked to OFSs or IFSs, and were, therefore, discarded from the comparison scheme. Both farms conduct agri-touristic activities. Besides farm comparisons, which permitted the collection of information on how to solve the issue on the farm level, comparisons of single farms with environmental thresholds were also settled in order to study how representative farms impact on ecological health of Val d'Elsa. Threshold values are shown in Table 4 (right-hand-side columns, sub-phase 2.2) together with corresponding bibliographical sources and farm results.

Next, the selected management systems were defined, both conceptually and legally (sub-phase 2.3). Following Mannion (1995), organic farming is a *holistic view of agriculture that aims to reflect the profound interrelationship that exists between farm biota, its production and the overall environment*. From a legal viewpoint, the OFS analyzed in this study complies with the stipulation of the EU Regulation

Table 3. Complete AESIS list of environmental critical points, systems, indicators and relevant procedures with corresponding selections for sustainability evaluation of farming systems in Val d'Elsa, Tuscany (in italics critical points, indicators and procedures selected for this study from the complete AESIS list, Pacini *et al.*, 2009).

Critical point	Environmental system	Indicator	Indicator procedure
Water demand, water-table level		Water balance	Water use with farm records (Fa, Pr) Percent of recycling of irrigation water (Fa, Pr)
Flood risk, water stagnation, <i>landscape conservation</i> <i>Soil erosion</i>	Water	<i>Drainage system length</i> <i>Soil erosion</i>	<i>In-field observations (Fi, P&P)*</i> <i>Potential risk of soil erosion (S, P&P)^o</i> <i>Soil cover index during year and erosivity critical period (Fi, Pr)[#]</i>
Soil quality Loss of organic matter	Soil	Soil salinity, Heavy metals Soil organic matter content	Chemical analyses (S, Pe) Organic matter balance with farm records (Fa, Pr) Chemical analyses (Fa, Pe)
Agro-ecological identity of fields		Field size Field max width/length ratio Rotation years <i>Crop diversity</i>	Map and In-field observations (Fi, P&P) Map and In-field observations (Fi, P&P) Farm records, In-field observations (Fa, P&P) <i>Map and in-field observations on field adjacency and density (Fi, Pr)*</i>
<i>Landscape diversity</i>	Production activities		
Livestock biodiversity Livestock intensity		Livestock biodiversity Livestock load Manure management	Farm records (Fa, Pr) Farm records (Fa, Pr) Liquid manure load (Fa, Pr)
Wastes		Dangerous waste load Percent of recycling waste	Farm records (Fa, Pr) Farm records (Fa, Pr)
<i>Associated biodiversity of flora</i>	Biodiversity	<i>Herbaceous plant biodiversity and richness</i> <i>Hedge biodiversity</i> <i>Arboreal plant biodiversity and richness</i> Semi-natural habitat areas	<i>Farm records on number of species (Fa, Pe)*</i> <i>In-field observations (Fi, P&P)*</i> <i>Map and in-field observations (Fi, Pr)⁶</i> Farm records, In-field observations (Fa, P&P)
Nitrogen cycle		Nitrogen leaching Nitrogen run-off Soil Nitrates Ammonium emissions	Nitrogen balance with farm records (Fa, Pr) Nitrogen balance with farm records (Fa, Pr) Chemical analyses (Fi, Pr) Nitrogen balance with farm records (Fa, Pr)
Phosphorous cycle	Flow system	Phosphorus sediment Soil phosphates	Phosphorus balance with farm records (Fa, Pr) Chemical analyses (Fi, Pr)
<i>Biocide pollution</i>		<i>Environmental potential risks of pesticide use</i>	LQ (Fi, P&P), EPRIP index (Fi, P&P) [^]
Energy demand		Energy balance	Farm records (Fi, Pr)

Fi, field; S, site; Fa, farm; P&P, production and pedo-climatic factors; Pr, production factor; Pe, pedo-climatic factor; LQ, leached quantity; EPRIP, environmental potential risk indicator for pesticides. *Complete procedures are presented in Pacini (2003), pages 148-152; ^ocomplete procedure is presented in Manrique (1986); [#]complete procedure is presented in Vereijken (1994), page 87. [^]complete procedure is presented in Padovani *et al.* (2004).

2092/91 (EEC, 1991) on organic production of agricultural products. For IFSs, the definition of El Titi (1992) was selected, which describes IFSs as a *holistic pattern of land use which integrates natural regulation processes with farming activities to achieve maximum replacement of off-farm inputs and to sustain farm income*. The IFS analysed in this study met the requirements of the integrated farming code of the 2000-2006 Tuscany Region rural development plan (TRRDP), which enforced the EU Regulation 1257/99 (EC, 1999).

Phase 3. Evaluating alternative solutions

In this phase, calculation methods of indicators were selected that met the requirements of the present type of application purpose (i.e., ordinary farms, sub-phase 3.1). One procedure was selected for each indicator identified in the definition phase of the sustainability issues (Table 3, Column d, in italics). The method and procedure sources, as well as the descriptions are indicated in Table 3. Indicators were measured and relevant results are shown in Table 4 (sub-phase 3.3). Results show that the OFS on La Sorbigliana achieved a higher performance in terms of planned (arboreous plant biodiversity, APB, and hedge biodiversity, HB) and associated (herbaceous plant biodiversity, HPB) biodiversity, and environmental potential risk indicator for pesticide use (EPRIP). In contrast, the IFS on the Poggio ai Grilli farm showed better

results in terms of crop diversity (CD), drainage system length (DSL), potential risk of soil erosion (PRSE) and soil cover index (SCI). By examining the site level, a large within-farm heterogeneity can be noticed with regard to the OFS indicators of APB, DSL and EPRIP, and the IFS indicators of HB, DSL and EPRIP. OFS EPRIP heterogeneity is due to the fact that the only treated crops, i.e. vine and olive, were located in Site 1. DSL was found to be equal to zero in the flat sites of both the organic and IFSs.

As far as comparisons with environmental thresholds are concerned, the OFS showed non-sustainable results for DSL, PRSE and SCI. The latter two need to be interpreted in a combined manner as PRSE provides a measure of soil erodibility and rainfall erosivity but does not consider management practices, while SCI represents the impact of farm choices regarding the land use (Lazzerini and Vazzana, 2005; Vazzana *et al.*, 1997; Vereijken, 1999). In the OFS, notwithstanding the above-threshold risk of soil erosion (PRSE of 9 against a threshold value of 8), the land use does not allow for a high enough level of soil cover to avoid erosion phenomena (SCI of 51% against a threshold value of 60%). In the case of the IFS, the opposite applies. Even if the risk of soil erosion is higher than that of OFS (i.e. PRSE equal to 10 vs. 9), the combination of the use of living mulches in vineyards with the land use allowed for sustainable levels of SCI (SCI equal to 84%). Besides PRSE, other non-sustainable values were reported for APB, HB

Table 4. Results of environmental indicators on site and farm scales of the case-study farms.

	Integrated farm			Organic farm			Farm	TV	TT
	Site 1	Site 2	Farm °	Site 1	Site 2	Wood site			
Drainage system length, m/ha	520	0	383	191	0	-	71	140 ^a	Lower*
Potential risk of soil erosion, score/ha	9	11	10	9	9	-	9	8 ^b	Upper ^o
Soil cover index, %	78	100	84	46	54	-	51	60 ^c	Lower
Crop diversity, score/ha	1295	877	1182	1164	338	-	646	30 ^d	Lower
Herbaceous plant biodiversity, score/ha	91	98	93	169	112	-	138	48 ^e	Lower
Hedge biodiversity, m/ha	41	0	30	78	137	0	115	60 ^f	Lower
Arboreous plant biodiversity, %	0	0	0	0	6	58	12	5 ^g	Lower
EPRIP, score/ha	80	120	92	27	0	0	9	81 ^h	Upper

TV, threshold value; TT, threshold type; *lower bound; °upper bound. EPRIP, environmental potential risk indicator for pesticides. ^aLandi, 1999; ^bLazzerini e Vazzana, 2005; ^cManrique, 1986; ^dVereijken, 1999; ^eSmeding, 1995; ^fPacini, 2003; ^gSchotman, 1988; ^hVereijken, 1999; ⁱPadovani *et al.*, 2004.

Table 5. Action table with indications of threshold compliance per indicator and of sustainable farming practices on site and farm scale in studied farms.

	Integrated farm			Organic farm			Proposed intervention	
	Site 1	Site 2	Farm °	Site 1	Site 2	Wood site		
Drainage system length	☺	☹	☺	☺	☹	-	☹	Construction of the drainage system on site 1 of the integrated farm and site 2 of the organic farm
Potential risk of soil erosion	☹	☹	☹	☹	☹	-	☹	Introduction of living mulch on sites 1 and 2 of the organic farm
Soil cover index	☺	☺	☺	☹	☹	-	☹	
Crop diversity	☺	☺	☺	☺	☺	-	☺	
Herbaceous plant biodiversity	☺	☺	☺	☺	☺	-	☺	
Hedge biodiversity	☹	☹	☹	☺	☺	-	☺	Planting hedges on sites 1 and 2 in the integrated farm
Arboreous plant biodiversity	☹	☹	☹	☹	☺	☺	☺	Reforestation of part or all of un-cultivated land in the integrated farm (1.1 ha on site 1 and 1.5 on site 2), and part of uncultivated land of site 1 in the organic farm
Environmental potential risk indicator for pesticides	☺	☹	☹	☺	☺	☺	☺	Reduction in the number of pesticide treatments (for mancozeb and tebuconazole)

and EPRIP. In the majority of cases, the non-sustainability of the system depended univocally on all corresponding site values. However, for DSL, site values of some indicators showed opposite results when compared to the thresholds (APB for OFS and EPRIP for IFS). Results of threshold comparisons were visualised for the last step of this phase by drawing farm-specific spider diagrams (Figure 1) and by providing a corresponding action table to advice farmers (Table 5) (sub-phase 3.4).

Discussion

In this section, the AESIS method application to ordinary farms is discussed with reference to the relevant phases (Table 2) in the procedure; thereafter a commentary on the different impacts of organic and IFSs for the two farms under survey was provided. The main challenge to the application of AESIS to projects including large samples of ordinary farms is to combine a systemic evaluation of FSs with the scarcity (financial and time) of resources that can be allocated for each farm. Extensive surveys accounting for high numbers of farms are subject to fund and labour dispersion. Maintaining a holistic view of the agroecosystem involves taking into consideration the entire range of sectorial environmental critical points and farm environmental systems, while simultaneously assigning specific attention to those that are considered to be of local importance. In this study, the solution adopted in two pilot farms was to identify a small set of indicators covering all the environmental systems with at least an indicator (AESIS Phase 1), and to choose simplified calculation procedures (Phase 3).

In Phase 2, the comparison layout was constructed by reducing the range of investigated management systems/practices to only two alternative options (i.e., OFS and IFS). Such a choice may have large impact on the process of selection of solutions. If other management solutions such as environmental management systems (EMS) or conventional farming were included in the analysis, then this would result in a more robust solution space for the sustainability issues identified in Val d'Elsa, but would also cost more in terms of financial requirements for the survey. This is an important "political" point that needs to be considered in the settlement phase of the sustainability evaluation exercise. Another issue arising with regard to Phase 2 is the collection of information on environmental thresholds. Irving and Moncrieff (2004) stated that environmental thresholds should be selected according to local pedo-climatic and production characteristics. In the present study, the thresholds applied were retrieved from other studies carried out in Tuscany. As a result, a given level of approximation in terms of outcomes of the comparison had to be accepted.

For the purpose of simplifying the AESIS application, two steps were discarded, that is the identification of policy measures (sub-phase 2.4) and the integration of indicators in a farm simulation model (sub-phase 3.2).

The AESIS was constructed with three different application purposes: i) detailed model-based analyses for the evaluation of organic, integrated and conventional farming systems (OFS, IFS and CFS, respectively) and for policy planning; ii) application to micro-farms on a long term experimental station to prototype organic arable FSs and to compare organic and conventional farming practices; iii) application to ordinary farms for the development of farm environmental management systems (EMS) and for evaluating organic, integrated and conventional FSs. Although a number of nuances occur between these three groups, each corresponds to the needs of relevant end-user groups, namely policy-makers, technicians and farmers, respectively. Hence, particular attention focussed on selecting transparent and meaningful-for-farmer indicators as well as straightforward result visualisation tools, such as action tables (Table 5) and spider diagrams (Figure 1), largely applied in the literature (e.g., Nicholls *et al.*, 2004).

In conclusion, since the AESIS method was adapted for applications

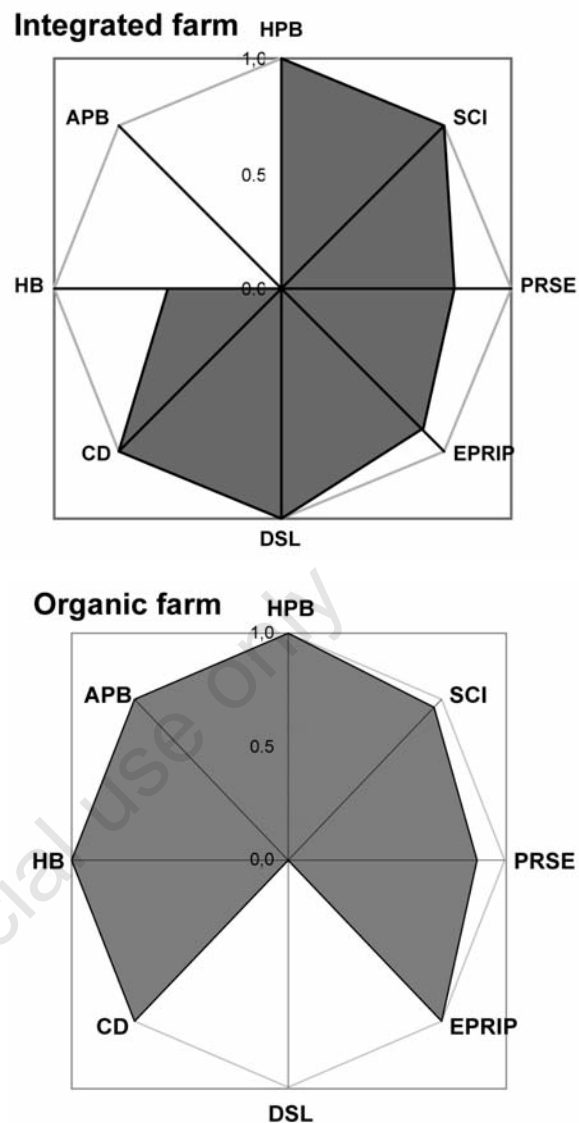


Figure 1. Spider diagrams of agro-environmental results of the organic and IFS. Non-sustainable and sustainable performances are visualised in light and dark grey, respectively. The score 1 corresponds to the threshold value of corresponding indicators. HB, hedge biodiversity; APB, arboreous plant biodiversity; HPB, herbaceous plant biodiversity; SCI, soil cover index; PRSE, potential risk of soil erosion; EPRIP, environmental potential risk indicator for pesticides; DSL, drainage system length; CD, crop diversity.

in ordinary farms, it proved to be sufficiently flexible for both the particular research and end-user requirements of this type of application purpose. Financial and time costs were also measured. Financial costs amounted to about 120.00 Euros per farm due to soil chemical analyses; personnel employment for AESIS application was as reported in Table 6. Results on financial and time costs are compatible to those previously reported by farmers' organisations (Lazzerini, 2001).

Results of agro-environmental indicators highlight the between-farm differences in terms of impact of organic and IFSs, and of within-farm heterogeneity on site scale due to the combination of pedo-climatic and production factors. The OFS, in general, showed better results than the IFS. However, especially for those management areas not constrained by organic agriculture legislation, performance was found to be worse than that of IFS, and sometimes also scarce in terms of com-

Table 6. Action table with indications of threshold compliance per indicator and of sustainable farming practices on site and farm scale in studied farms.

AESIS phase	AESIS step	Time (days)
Definition of the sustainability issues	Identify issues related to sustainability Identify detailed critical points and connect them to farm environmental and production systems Choose indicators	1.0
Problem-solving approach to the sustainability issues	Settle a comparison layout Identify indicator thresholds Describe management systems	2.0
Evaluating alternative solutions	Select calculation methods of indicators proportional to the evaluation purpose Measure indicators: data collection on farm structure crop record cards field data collection on biodiversity collection of soil samples data processing Present and analyse results	1.0 0.5 0.5 2.0 0.5 4.5 0.5
Total		12.5

pliance with thresholds. Such outcomes were utilized to define a number of indications of practices to be followed in order to improve farm-level performance for both the organic and the IFS (Table 5). Even if a preliminary analysis on the representativeness of the two case-study farms for Val d'Elsa was carried out based on pedo-climatic conditions and land use, a trivial generalisation of results presented in this paper for the entire area is not possible due to such a small sample and the moderate level of detail of the representativeness analysis (for more complex farm typology and representativeness approaches reference is made to Righi *et al.*, article in press); rather, results of the two integrated and organic FSs should be used as indications for further analyses.

Conclusions

The main aim of the present paper was to present the results of the application of the AESIS framework to two organic and IFSs in Valdelsa, Tuscany, and to discuss the application of the method to ordinary farms. After adequate selection of indicator procedures, the AESIS framework proved to be sufficiently flexible for ordinary farm applications while concomitantly maintaining a holistic perspective and considering pedo-climatic and production factors on different spatial scales. The OFS showed better results than the IFS, especially for those aspects subject to organic production rules. A number of indications for improving farm performances of sustainability were proposed for both the organic and the IFS. Moreover, an additional practical use of the AESIS application to ordinary farms is proposed and involves drafting environmental analyses of environmental management systems in compliance with ISO 14000 norms or Regulation (EC) 761/2001 promoting the adoption of eco-management audit schemes (EMASs) in the EU (EC, 2001). Such norms would then lead to the environmental certification of farms, which would help in promoting agri-tourism in a high environmental quality area such as Val d'Elsa.

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