AN OPERATIONAL SYSTEM FOR EVALUATING SUSTAINABILITY OF ORGANIC, INTEGRATED AND CONVENTIONAL FARMING SYSTEMS

C. PACINI*, G. LAZZERINI**, C. VAZZANA**, G. GIESEN***, A. WOSSINK****

**Farm Management Group – Department of Social Sciences, Wageningen University*
Hollandseweg 1 - 6706KN Wageningen (NL) - E-mail: Cesare.Pacini@alg.abe.wau.nl,
***Department of Agronomy and Land Management, Florence University*
****Department of Social Sciences, Wageningen University*
*****Department of Agricultural & Resource Economics, NC State University*

Abstract

Agricultural researchers widely recognise the importance of sustainable agricultural production systems and the need to develop appropriate methods to measure sustainability. The principal purpose of this paper is to evaluate the financial and environmental aspects of sustainability of Organic, Integrated and Conventional Farming Systems (OFS, IFS, and CFS, respectively) at farm and more detailed spatial scales. This is achieved applying an integrated economic-environmental accounting framework to three case study farms in Tuscany including different farming systems and different spatial scales. The environmental performances of the FS were measured through the application of an Environmental Accounting Information Systems (EAIS) at field, site and farm level. The EAIS indicators were then integrated with (1) a set of financial indicators to evaluate the economic and environmental trade-offs between different FS and (2) with information on the regional and site-specific soil and climate conditions to study the impact of different pedo-climates on the environmental performances of the FS. The gross margins of steady-state OFS were found to be from 5,6 % to 8,6 % higher than the corresponding CFS gross margins. OFS perform better than I/CFS with respect to nitrogen losses (12,1-21,0 versus 33,3-38,8 kgN/ha), pesticide impact (0 versus 1-41 score/ha), herbaceous plant biodiversity (69-124 versus 52-117 score/ha) and most of the other environmental indicators. However, on hilly soils, erosion revealed to be higher in OFS than in CFS (3,9 versus 1,4 t/ha). The pesticide and the nitrogen indicators showed, for this example, that the environmental impact due to integrated and conventional farming practices is similar. Regional pedo-climatic factors resulted to have a considerable impact on nutrient losses, soil erosion, pesticide impact and herbaceous plant biodiversity, site-specific factors on nutrient losses and soil erosion. Results at the field level suggest that herbaceous plant biodiversity and crop production are not always conflicting variables. Conclusions are drawn on the possible practical applications of the method for environmental measures in the agricultural sector.

Key words: sustainable farming systems, organic agriculture, environmental accounting, indicators

1. Introduction

Agricultural researchers widely recognise the importance of sustainable agricultural production systems and the need to develop appropriate methods to measure sustainability. Modern society increasingly values sustainable farming systems for their potential to produce wildlife and landscape values and to decrease the environmental harm due to farming practices. Against this background an increasing body of literature has developed on the quantification of the sustainability of agricultural production. Usually, this literature promotes the idea of monitoring a range of sustainability indicators out of the recognition that sustainability cannot be condensed to a single definition (Pannell and Glenn, 2000). Most of these indicators are strongly ecological in focus and very detailed or they are either policy oriented and developed at the aggregate, sector or country level. In either case these indicators lack a close link to farm management decision making. Indicators at the level of the agricultural production processes enable finding the right balance between production economics and environmental goals right there where the production decision are made (Halberg, 1999). This balance has to take into account both production and pedo-climatic factors at farm and more detailed levels. Against this background, the aim of the present paper is to evaluate the financial and environmental aspects of sustainability of organic, integrated and conventional farming systems at farm and more detailed spatial scales. This is achieved applying an integrated economic-environmental accounting framework to case study farms in Tuscany. Because of the lack in literature of farm and lower spatial scale analyses and detailed data, the present experiment was designed to be implemented on three farms, privileging the depth of the analysis in respect to the sample size.

2. Material and Methods

2.1. Overview

Measurement of sustainability was carried out for the 1998-2000 period on three farms including different farming systems (conventional, integrated and organic) at different spatial scales. For the definitions of Organic and Integrated Farming Systems (OFS and IFS, respectively) used in this paper, reference is made to Mannion (1995), Rigby and Cáceres (2001) and El Titi (1992). From an application viewpoint OFS analyzed in this study are enforced on the basis of the prescriptions of the EU regulation n. 2092/91 on organic production of agricultural products and the Tuscany L.R. (Regional Law) n. 54/95 (recently updated by the EU regulation n. 1804/99) on organic livestock production. IFS analyzed in this study are enforced on the basis of the integrated farming code of the EU regulation n. 2078/92 Tuscany Region agro-environmental enforcement program (recently updated by the 2000-2006 Tuscany Region Rural Development Plan, which enforces the EU regulation 1257/99). Farmers who complied with the over-mentioned prescriptions received payments in accordance with what stated by the EU Reg. n. 2078/92 and 2772/95. Under these regulations, farmers who enforced integrated and organic farming methods received an aid of 181,1 ECU per hectare for annual crops for which a premium per hectare is granted under the market regulations (e.g., cereals and oilseeds), 301,9 ECU per hectare for the other annual crops (e.g., seeds and grain legumes) and 60,38 ECU per hectare for temporary grasslands. (In 1998 1 ECU corresponded to 1973 It. Lire, currently 1,02 €).

2.2. The Environmental Accounting Information System

Data collection and processing of the environmental indicators for the measurement of sustainability were performed through the application of an Environmental Accounting Information Systems (EAIS). The information system was designed following a holistic approach which takes into account simultaneously all the components of the agro-ecosystem. The EAIS was organised into several systems and modules (i.e., sub-systems). The modules were chosen on the basis of environmental critical points observed in Tuscany physiographic areas. Within each module a number of environmental processes take place which affect the given critical points. The performance of the management of each environmental process was quantified by a set of environmental indicators. The EAIS was built to be implemented at different levels of analysis ranging from (a) a high level to (b) a low detailed level. The a-level is meant to be applied on representative farms for research purposes aimed at the planning and monitoring phases of policy design. The b-level should be applied on ordinary farms for the auditing and monitoring phases of policy implementation. In this paper results focus on the a-level. For more details on the EAIS structure, reference is made to Pacini *et al.* (2001). Besides the environmental indicators, a set of financial indicators was calculated, namely the gross margins from production processes, outputs, incomes from compensatory payments and agro-environmental measures, costs for fertilisers and pesticides, ecological infrastructure (surface drainage system and hedges) maintenance costs and other variable costs. The EAIS indicators together with the financial indicators form an integrated economic-environmental accounting framework that was used to evaluate the environmental and financial aspects of sustainability at farm and more detailed scales.

2.3. Environmental indicators and hierarchical levels

In figure 1 the selected indicators are placed in relation to their corresponding calculation reference spatial scale.

INCREASED SPATIAL INFO DETAIL

FARM LEVEL ANALYSIS

FARM FINANCIAL INDICATORS

Systems and Modules	FARM ENVIRONMENTAL INDICATORS
Refuse management	Dangerous Waste Product Indicators
Cattle production	Livestock Load Indicator, Livestock Biodiversity Indicator

SITE LEVEL ANALYSIS

SITE FINANCIAL INDICATORS

Systems and Modules	SITE ENVIRONMENTAL INDICATORS
Water balance	Water Use Indicator
Drainage system	Surface and underground drainage system lengths
Soil morphology and structure	Terrace length, Soil erosion
Soil chemical components	Soil Salinity Indicator, Soil organic matter content
Plant production	Crop Diversity Indicator
Flora	Arboreous Plant and Hedge Biodiversity Indicators
Nitrogen balance	Nitrogen leaching, Nitrogen run-off
Phosphorus balance	Phosphorous sediment
Crop protection	Environmental Potential Risk Indicator for Pesticides
Energy	Energy Indicator

FIELD LEVEL ANALYSIS

CROP FINANCIAL INDICATORS

Systems and Modules	FIELD ENVIRONMENTAL INDICATORS
Plant production	Crop rotation blocks, Field size, Field max width/ max length ratio
Flora	Herbaceous Plant Biodiversity Indicator
Fauna	Insect Biodiversity Indicator

INCREASED ANALYSIS AGGREGATION LEVEL

Figure 1: General overview of environmental and financial indicators and their spatial scales

Depending on specific purposes, each indicator can be aggregated and used at higher levels than the one in which it is calculated. Four agronomic-physiographic spatial scales are used in this study, namely field (a portion of a site limited by ecological infrastructures), site (4-200 ha), landscape (200-4000 ha) and region (thousands of square kilometres). In this study the landscape scales coincide with the farm management units. Being landscapes chosen as representative of their corresponding regions, differences between the impacts of regional pedo-climates were studied by means of farm analyses. For the definitions of site, landscape and region and for further details on spatial and temporal scales in agro-ecosystem analysis and management reference is made to Prato (2000), Schleusner (1994), Bailey (1988) and De Ridder (1997).
The integrated economic-environmental framework was applied to the three selected farms (table 1).

Table 1: General description of the case-study farms

Farms	**Le Rene**	**Alberese**	**Sereni**
Region	S. Rossore Regional Park	Maremma Regional Park	Mugello basin
Climate	Mediterranean moist	Mediterranean dry	Pre-mountain
Landform	Flat	Flat and hilly	Flat and hilly
Farm type	Arable	Mixed cattle-arable-horticultural-arboricultural[1]	Mixed dairy-arboricultural[1]
Farming system	Organic and Conventional	Integrated and organic	Organic
Total area	476 ha	3441 ha	352 ha
Agricultural area used[2]	452 ha	593 ha	156 ha
Livestock - C/*I*FS	-	*110 horses, 460 beef cows*	313 dairy cows
Livestock - OFS	-	102 horses, 389 beef cows	241 dairy cows

[1] Arboricultural crops are disregarded in this paper
[2] Permanent pastures excluded

Le Rene is an organic farm that until the end of 1999 used to have also an area cultivated conventionally. The Alberese farm used to be an integrated mixed farm. At the beginning of 1999 a three-year period of conversion to organic agriculture was started, ergo during 1999 and 2000 only organic production techniques were used on the farm. The Sereni farm is an organic farm whose conversion period was terminated in 1995 and operates fully as an organic farm since then.
To perform detailed level analysis farms were divided into sites (table 2). Sites were identified on the basis of landform, soil and irrigation conditions. Site-representative rotations were identified on the basis of temporal succession and spatial distribution of the crops. Besides the crops of the site-representative rotations, on the Alberese farm small portions of farmland are cropped with broad bean, tomato, chickpea and bean. On the Le Rene site 3 in 1998 sugar beet has been cropped as well. In addition to the farm and the site levels, fields were identified as the lowest hierarchical levels on the basis of the ecological infrastructure network.

Table 2:- Description of the sites on the three selected farms

Farms/ Sites	**Land-Form**	**Soil geological classification**	**Soil physical classification**	**Irrigation**	**OFS rotation**	**C/I FS rotation**
Le Rene						
Site 1	Flat	Alluvial plain	Clay	Not irr.	S-C-FL-C	-
Site 2	Flat	Alluvial plain	Silt loam	Not irr.	-	W
Site 3	Flat	Alluvial plain	Clay loam	Not irr.	-	W
Site 4	Flat	Peat soil	Peat	Not irr.	Set-aside	
Alberese*						
Site 1	Flat	Terra rossa	Silt loam	Not irr.	Permanent pasture	
Site 2	Flat	Alluvial flat	Silty clay loam	Not irr.	S-W	W
Site 3	Flat	Floodplain	Silty clay loam	Irrigated	S-3A-MG-C	S-L-W
Site 4	Flat	Salt field	Silty clay loam	Not irr.	Permanent pasture	
Sereni						
Site 1	Hilly	Alluvial slope	Clay	Not irr.	B-BB	3A-4G
Site 2	Hilly	Alluvial slope	Sandy clay	Not irr.	MS-B-BB-MS-4G	3A-4G
Site 3	Flat	Alluvial terrace	Clay loam	Not irr.	MS-B-BB-MS-3A	MS-B-R-3A
Site 4	Flat	Alluvial terrace	Clay loam	Irrigated	MG-B-MG-3A	MS-B-R-3A
Site 5	Flat	Alluvial valley floor	Loam	Irrigated	MG-B-MG-3A	MG
Site 6	Flat	Alluvial valley floor	Loam	Not irr.	MS-B-BB-MS-3A	MS-B-R-3A

The Alberese farm has also a fifth site which is destined for woodland

Legend: S = Sunflower; C = winter Cereals (on the Le Rene site 1: 85% of hard wheat, 15% of spelt and rye; on the Alberese site 3: 85% of hard wheat and 15% of barley); FL = Forage Legumes (on the Le Rene farm: clover, alfalfa-seed, sweet vetch-seed, broad bean); W = hard Wheat; A = Alfalfa; MG = Maize Grain; L = annual Leys (on the Alberese farm: clover-oats association, vetch-oats association, Italian ryegrass); B = Barley; BB = Broad Bean; G = Grassland; MS = Maize Silage; R = Italian Ryegrass.

2.4. Processing methods for indicators

In this paper results are presented of selected environmental indicators, namely the nutrient, erosion, pesticide and biodiversity indicators. Nutrient and erosion indicators were calculated with the GLEAMS model (Knisel, 1993). Calculations were carried out for site-representative fields on a rotational temporal scale. Results were reported as annual averages of the reference period. The pesticide indicator was calculated with the EPRIP (Environmental Potential Risk Indicator for pesticides) yardstick (Trevisan *et al.*, 1999). Calculations were carried out for site-representative fields on a year scale. For comparison purposes, both GLEAMS and EPRIP programs were run using 1998 climatic data for all the FS. Data on biodiversity indicators were collected at field (Herbaceous Plant Biodiversity Indicator - HPBI) and site

level (Arboreous Plant Biodiversity Indicator - APBI, Hedge Biodiversity Indicator - HBI, and Crop Diversity Indicator - CDI) during the 1998-2000 experimental period. Results were reported as annual FS averages or, to study year effects, on a year scale. For more details on environmental indicator processing methods refer to Pacini *et al.* (2001).
As to the financial indicators, outcomes refer to 1998 prices. For the Le Rene and the Alberese farm, prices, yields, area compensatory payments (EU regulation n. 1765/92), integrated and organic measure payments (EU regulation n. 2078/92) were reported from the RICA-FADN. Net crop productive factor inputs were obtained by excluding the variable costs of ecological infrastructures from the RICA-FADN crop-attributed total value. For the Sereni farm, which does not participate in the Tuscany RICA-FADN, data were collected with standard crop record cards.

3. Results

Starting from data of the three farms under study, the accounting framework is used here to compare the impact of conventional, integrated and organic farming systems on financial returns and the agro-ecosystems within farms. Comparisons between impacts of pedo-climatic factors at different spatial scales are considered as well (between farms belonging to different landscapes/regions and between sites of the same farm). Because of space reasons, in this paper results are presented of selected indicators, namely the nutrient indicators, the soil erosion, the EPRIP and the biodiversity indicators.
Table 3 summarizes the financial and environmental results of the selected indicators at the system level for the three case study farms.

Table 3: Summary of financial and environmental results for the Organic (O), Integrated (I) and Conventional Farming Systems (CFS) at the case-study farms

Farm		**Le Rene**		**Alberese**		**Sereni**	
Farming system		OFS	CFS	OFS	IFS	OFS	CFS
Gross margin (€/ha a.a.u. less p.p.)		953	902	429	450	2191	2017
Nutrient, Erosion and Pesticide Indicators	N leaching (kg/ha a.a.u.[1] less p.p.[2])	10,8	25,8	10,6	32,0	17,1	28,3
	N run-off (kg/ha a.a.u. less p.p.)	10,0	10,9	1,5	1,3	3,9	10,5
	N losses (kg/ha a.a.u. less p.p.)	20,8	36,7	12,1	33,3	21,0	38,8
	P sediment (kg/ha a.a.u. less p.p.)	0,1	0,2	0,1	0,0	2,6	0,6
	Soil erosion (t/ha a.a.u. less p.p.)	0,0	0,1	0,0	0,0	3,9	1,4
	EPRIP (score/ha a.a.u. less p.p.)	0,0	7,8	0,0	1,0	0,0	41,0
Biodiversity Indicators	Herbaceous Plant Biodiversity Indicator (HPBI) (score/ha total area less woodland)	69	52	124	117	73	n.a.[3]
	Arboreous Plant Biodiversity Indicator (APBI) (% total area)	3,4	9,6	44,0	44,0	41,0	41,0
	Hedge Biodiversity Indicator (HBI) (m/ha a.a.u. less p. p.)	9,3	0,0	23,8	23,8	67,3	0,0
	Crop Diversity Indicator (CDI) (score/ha)	4,8	1,8	4,0	3,4	17,3	n.a.

[1] Agricultural area used
[2] Permanent pastures
[3] Not applicable

In the following, results are analysed in more detail. As to the environmental indicators, results are presented at farm level for both system and pedo-climatic impacts. Site level analysis focus on the soil component of the pedo-climatic impact (i.e., same climate but different soils) while the field level analysis treats system comparisons at a more detailed spatial scale.

3.1. Financial results

Table 4 summarizes the financial results of the different FS on the Le Rene, Alberese and Sereni farms. The OFS gross margins on the Le Rene and the Sereni farm were found to be 5,6 % (953 versus 902 €/ha) and 8,6 % higher (2191 versus 2017 €/ha) than the corresponding CFS gross margins,

respectively. In both cases results were mainly determined by a combination of higher prices for organic products, the organic agriculture 2078 payments, lower OFS yields and lower variable costs for fertilizers (only for Sereni OFS) and pesticides. On the Alberese farm the gross margin decreased by the 4,7 % (429 versus 450 €/ha) in the first year of conversion. This is primarily due to the fact that, while yields decrease, the farm products cannot get higher prices as they cannot be certified as organic before the end of the three-year conversion period. Higher 2078 payments and lower costs for fertilizers and pesticides for the OFS only partially cover this difference. The ecological infrastructure maintenance costs, which are comprised in the "other variable costs" item, resulted to be irrelevant.

Table 4: Comparison of financial results (€/ha) for the O, I and CFS

Farm	**Le Rene**		**Alberese**		**Sereni**	
Farming system	OFS	CFS	OFS	IFS	OFS	CFS
Incomes						
Output	730	722	609	779	2135	2350
1765 Compensatory payments	333	480	263	324	207	126
2078 Agri-environmental p.	187	0	156	130	146	0
Total	1250	1202	1028	1233	2488	2476
Variable costs						
Fertilizers	90	71	40	61	0	46
Pesticides	0	28	0	33	0	61
Other costs	207	201	559	689	297	352
Total	297	300	599	783	297	459
Gross margin	953	902	429	450	2191	2017

Focusing on the agro-environmental measures, the Sereni farm 2078 payments (146 €/ha) are lower than the O/CFS gross margin difference (174 €/ha - 2191 versus 2017 €/ha). On this farm also the 1765 compensatory payments are higher for the OFS.

On the Le Rene farm the 2078 payments (187 €/ha) are decisive for the achievement of the OFS higher gross margin (51 €/ha - 953 versus 902 €/ha). However, a large share of the agro-environmental extra-income is used to compensate for the decrease of the compensatory payments due to the extensification of the rotations under the OFS (147 €/ha - 333 €/ha versus 480 €/ha).

On the Alberese farm the income increase due to the agro-environmental measures (26 €/ha - 156 versus 130 €/ha) is largely overwhelmed by the compensatory payment decrease (61 €/ha - 263 versus 324 €/ha).

3.2. Environmental results

3.2.1. Nutrient losses and soil erosion

Farm level analysis. In table 3 results on nitrogen leaching, run-off, phosphorous sediment and soil erosion are displayed. Results of these indicators are treated together because all of them were calculated with GLEAMS. OFS performs better than I/CFS for nitrogen leaching in all the three farms. On the Sereni farm, whose land is partially on hilly soils, OFS is worse than CFS as to phosphorous sediment and soil erosion. This depends on the implementation of long rotations under the OFS, which implies the cropping on hilly soils of more machine requiring crops (i.e., maize, barley, broad bean) compared to those (only grassland and alfalfa) under the CFS.

Nutrient losses are highly affected by regional pedo-climatic conditions. The OFS nitrogen losses on the Alberese farm (12,1 kg/ha) are lower than on the Le Rene (20,8 kg/ha) and the Sereni farm (21,0 kg/ha). Specially considering the pedo-climatic factor, the IFS on the Alberese farm does not perform sensitively better for nitrogen losses than the CFS on the other two farms (33,3 versus 36,7 and 38,8 kg/ha), even worse for nitrogen leaching (32,0 versus 25,8 and 28,3 kg/ha). This seems to be due to a slight difference in the fertilizers amounts used with the IFS and the CFS.

Site level analysis. In table 5 nitrogen losses of the three farms are shown for cropped sites.

Farm	Le Rene			Alberese				Sereni											
Farming System	OFS	CFS		OFS		IFS		OFS						CFS					
Site	1	2	3	2	3	2	3	1	2	3	4	5	6	1	2	3	4	5	6
N losses (kg/ha)	20,8	47,9	34,2	11,5	12,2	20,2	34,6	18,1	7,3	33,4	33,1	28,8	16,8	12,9	15,9	49,9	43,0	73,7	37,7

Table 5: Comparison of nitrogen (N) losses for the O, I and CFS on cropped sites

High differences in losses under the same FS depend mainly on rotations. But again the soil factor is very decisive. Simulation results for the same rotations on different sites of the same farm and under the same FS show that the differences between nitrogen losses of the same rotations oscillate between a minimum of 15 % on the Sereni OFS (28,8 on site 5 versus 33,1 kg/ha on site 4) and a maximum of 40 % on the Le Rene CFS (34,2 on site 3 versus 47,9 kg/ha on site 2).

In table 6 the impact of rotations and soil physical characteristics on erosion is compared. Results are shown of site 1 and 2 of the Sereni farm, which are the only cropped sites having slopes. Sites Sereni 1 and 2 have equal slopes but the alfalfa/grassland rotation in site CFS 1 produces a level of erosion almost 100 % lower than the same rotation in site CFS 2 (1,9 versus 3,5 t/ha). This is due to the different soil conditions of the two sites (clay in site 1 and sandy clay in site 2). Results are inverted under the OFS, where the erosion produced by the barley/broad bean rotation in site 1 is triply in respect to that of the maize silage/barley/broad bean/maize silage/grassland rotation of site 2 (16,7 versus 5,5 t/ha). This means that in this case the management factor (rotation choice) overwhelmed the environmental factor (soil characteristics).

Table 6: Soil erosion for the O and CFS at site level on the Sereni farm

Farm	Sereni			
Farming System	OFS		CFS	
Site	1	2	1	2
Soil erosion (t/ha)	16,7	5,5	1,9	3,5

3.2.2. Pesticide risk

Farm level analysis. Table 3 displays results on environmental risk due to pesticides. OFS on the three farms produce no environmental risk. The Sereni CFS performs very poorly. This can be due to more intensive crop plan and techniques. In general EPRIP shows low impacts in relation to the EPRIP yardstick range of possible results (1-625). In fact, according to the EPRIP yardstick classification, the risk ranges from "none" on the Le Rene farm (EPRIP<=1), to "negligible" on the Alberese farm (2<=EPRIP<=16), to "small" on the Sereni farm (17<=EPRIP<=81).

In table 7 results of EPRIP are shown which compare the impacts of the different crop techniques (treatments, pesticide types) for winter cereals on representative sites of the three farms under survey.

Table 7: EPRIP score for winter cereals with different integrated and conventional crop protection techniques on representative sites

Farm	Le Rene			Alberese			Sereni		
Crop technique	**CFSr**[1]	IFS[2]	CFSs[3]	CFSr	**IFS**	CFSs	CFSr	IFS	**CFSs**
EPRIP (score/ha)	**1**[4]	4	8	1	**4**[4]	3	1	6	**61**[4]

[1] CFS crop technique of the Le Rene farm

[2] IFS crop technique of the Alberese farm

[3] CFS crop technique of the Sereni farm

[4] Results in bold refer to the actual crop techniques of each farm

Winter cereals, which are the only pesticide treated crops present on all the three farms, are barley on the Sereni farm, and durum wheat on the Le Rene and the Alberese farm. CFSr (CFS crop technique of the Le Rene farm) has the best EPRIP regardless of the pedo-climatic conditions or the farm types. On the Alberese farm the environmental impacts of the IFS crop technique, which is the actual technique applied on this farm, are the worst. The three crop techniques all perform best on the Alberese farm and the worst on the Sereni farm, which again emphasizes the decisive role of the regional pedo-climate.

Site level analysis. In table 8 results of EPRIP are displayed which compare the impacts of the crop protection techniques actually applied on the whole range of pesticide treated crops. The site level analysis reveals that there is not a relevant difference between the site-specific results of same crop protection techniques within the same farm. EPRIP scores per hectare change sensitively between different crops (e.g., score 1 for wheat versus 46 for sugar beet on the Le Rene site 3; score 61 for barley versus 119 for maize on the Sereni sites 3 and 4) but show only minor differences between the same crops of different sites of the same farm. In fact, a difference of 1 score is found only between the barley technique applied on the Sereni sites 3 and 4 (61 scores/ha) and the same technique applied on site 6 (60 scores/ha).

Table 8: EPRIP score for different crops and sites at the case-study farms

Farm	Le Rene		Alberese		Sereni						
Farming system	CFS		IFS		CFS						
Site	3		2	3	3		4		5	6	
Crop	wheat	s. beet	wheat	wheat	barley	maize	Barley	maize	maize	barley	maize
EPRIP (score/ha)	1	46	4	4	61	119	61	119	119	60	119

3.2.3. Biodiversity

Farm level analysis. As shown in table 3, the result of the HPBI is better for OFS than for I/CFS, both on the Le Rene and the Alberese farm. There are only minor differences between FS as to the Arboreous Plant Biodiversity Indicator. As far as hedges are concerned, both on the Le Rene and the Sereni farm, the management has accompanied the crop technique conversion with an improvement of these green infrastructures. The Crop Diversity Indicator (CDI) is always higher for the OFS. On the Alberese farm it increases during the conversion from 3,4 in 1998 to 4,6 in 2000. The management of biodiversity on the Sereni OFS as to ecological infrastructures (APBI and HBI) and crop plan (CDI) is the most accurate. This can explain the good result achieved for the HPBI, despite the more intensive land use on this farm (see gross margins). As to the pedo-climatic impact, the Alberese farm HPBI is far better than the OFS HPBI of the other two farms.

Site level analysis. In table 9 the HPBI trends during the conversion of the two cropped Alberese farm sites are shown (sites 2 and 3). Differences between site HPBI total values within the same farm depend more on the crop plan and/or the green spaces share than on the site intrinsic natural value. HPBI annual absolute values of wheat, other crops and green spaces are similar. When not, this seems to be due particularly to successful/unsuccessful weed control operations (e.g., the site 2 wheat value in 1998), coincidental circumstances (e.g., the site 2 1998 green spaces value, which is probably partly underestimated because of overgrazing in the sample), changing crop plans (e.g., the other crops values) or to the seed bank capacity of the monitored fields. Similar findings are obtained also in the other farms under survey.

Table 9: Field level HPBI results for two sites and different FS at the Alberese farm

Farming system	**IFS (1998)**		**OFS (1999)**		**OFS (2000)**	
Sites	2	3	2	3	2	3
Wheat HPBI absolute value (score)	1	33	73	71	38	49
Other crops HPBI absolute value (score)	n.a.[1]	110	116	67	91	66
Green spaces HPBI absolute value (score)	86	149	136	141	145	151
Site HPBI Total value (score/ha total area[2])	71	96	123	87	131	82

[1] Not applicable - no other crop on the site in 1998
[2] Less woodland

Field level analysis. In table 9 the HPBI absolute values of wheat, which was the only pesticide treated crop under the IFS, other crops and green spaces are presented as well. Wheat values increase in the first year of conversion and decrease again in 2000. This can be due to the improved management crop technique ability under the OFS and to an improved reaction of the agro-ecosystem to the new techniques. Average absolute values of the other crops are decreasing year by year. This decrease under the OFS can be explained by the introduction in the crop plan of more intensively cultivated cash crops. Green spaces absolute values are slightly increasing in the 3-year period. 2000 OFS wheat average (43,5) of site 2 (38) and 3 (49) is 32 % higher than the 1998 site 3 IFS value (33). Wheat cover decreases on Alberese site 2 from 1998 to 2000 only by less than 1 % (from 100^- to 99 %) and even increases on site 3 (from 95 to 98 %) during the same period. In steady-state FS changes differ. The Le Rene farm wheat HPBI is 34 under the CFS and 69 under the OFS (+103 %). Cover percentages decrease from 93 % in CFS to 88 % in the OFS (-5 %). These results can probably be attributed to the use of selective pesticides in I/CFS.

Discussion and conclusion

A holistic, integrated economic-environmental accounting framework is applied to three case-study farms to asses the sustainability of organic, integrated and conventional farming systems. The impact of farming systems on the indicators is studied together with that of pedo-climatic factors at farm, site and field level.

In this example, steady-state OFS financially perform better than CFS. However, systems in conversion can experience serious financial difficulties also due to the fact that in Tuscany the agro-environmental measures tailored to this farm condition are limited. Agro-environmental measures reveal to be non-decisive for the financial sustainability of the OFS on two of the case-study farms. Farm choices aimed at the implementation of the organic method depend rather on particularly favourable market prices (or price expectations) for organic products, which are not applicable on average to the other farms of the Region. Moreover, there seems to be a certain level of discordance between the agro-environmental measures and the CAP producers' support system (see the Le Rene and the Alberese farm results in section 3.1). This is particularly relevant under the current circumstances, where the EU aims are moving from the production support to the sustainability of rural systems and farmers' role is progressively shifting from that of food suppliers to that of custodians of the countryside.

As expected, OFS perform better than I/CFS with respect to most environmental indicators. However, on hilly soils, erosion and, consequently, phosphorous sediment reveal to be higher for OFS than for CFS. This can be explained by considering the OFS rotational constraints, which imply the cropping on hilly soils of more mechanized crops. Coiner *et al.* (2001) achieve the same conclusions also at landscape scale. EPRIP and the nitrogen indicators show, for this example, that the environmental impact due to integrated and conventional farming practices is similar. This is consistent with what found in literature. Bailey *et al.* (1999) report that there is no significant difference between the two systems with respect to beetles and spiders, earthworms and nitrate residues. Regional pedo-climatic factors result to have a considerable impact on nutrient indicators, soil erosion, EPRIP and HPBI, site-specific factors on nutrient indicators and soil erosion. Measuring this impact allow to evaluate the share of environmental harm/benefit which can be ascribed to the farm management choices (e.g., different FS). The field level analysis shows that herbaceous plant biodiversity and crop production are not always conflicting variables.

In conclusion, these findings provide evidence on to main aspects: 1) OFS have the potential to improve the efficiency of many environmental indicators as well as being remunerative, 2) the environmental responses of organic, as well as integrated and conventional FS can be highly affected by the pedo-climatic factors, both at regional and at site scale.

The EAIS should be also applied at district level on ordinary farms in order to check the procedures of data transfer from district representative farms, where the EAIS is applied for research purpose at a high detailed level, to ordinary farms, where the EAIS should be applied for auditing and monitoring purposes at a low detailed level.

Currently, there is a proliferation of policy interventions to enhance the environmental performances of the agricultural sector (e.g., agri-environmental measures, cross-compliance measures, EMAS, etc.).

These regulations require specific tools for the evaluation, the monitoring and the auditing of the production and environmental processes involved. The integrated financial-environmental accounting framework (EAIS plus financial accountancy) outlined in this paper seems to have the potential to approach many of those requirements. The accounting framework is: 1) *holisticly designed*, which allows the study of trade-offs between all the main environmental and production processes of an agro-ecosystem, therefore revealing possible conflicts among them; 2) *strictly connected* with the regional, site-specific and field pedo-climatic features, which is a basic step to improve the economic and environmental performances of farms and policy measures; 3) *flexible*, which means that has the potential to approach a vast range of environmental issues and farm types, selecting each time the most appropriate database (modular structure); 4) *complementary* as for data collection, because it can be matched with other farm information systems (e.g., the RICA-FADN, the compulsory pesticide record card, etc.).

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