An ecological footprint approach to environmental-economic evaluation of farm results

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Abstract

Farmers' cultivation choices affect the natural cycles of crops and impact their production. By assessing the farming activities, as influenced by crop types, land suitability and cultivation choices, the effectiveness of agricultural practices in terms of environmental impact can be evaluated. The relationships between agriculture and environment have to be carefully considered together with the economic performance, which is often taken as the unique or, at least, the main goal of other human activities.

The aim of this paper is to assess and to analyse in a comparative way the environmental and economic results of a crop production system at farm level.

The methodology for the evaluation of environmental performance is based on a modified version of Ecological Footprint account, used to measure the demand for natural resources linked to the farm's operations, which is compared with the Biocapacity of the crop system itself. The economic performances are assessed by means of crops analytical budgets.

The results provided by the case study analysis show that the considered farm cropping system reports an overall positive ecological balance (+2,4 gha) together with an acceptable gross margin (16,200 €). It emerges that crops with the worst environmental performances sustain the farm income, while the crops with a positive ecological balance bring a very limited contribution to economic profitability.

Such results lead to some considerations about the importance of carefully considering the trade-off between economic and environmental consequences of farming activities to drive farmers towards a more sustainable behaviour.

Keywords: Environmental/economic trade-off, Ecological Footprint, environmental impact, Agro-environmental performances

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1. Introduction

The public opinion is increasingly concerned with the relationship between environment and economy, both at the global and the local level. As a consequence, a lively debate is going on and it drives the regulatory and political framework to take care of these issues. Recently, the attention has been focused on the role of the agricultural systems, namely the management of natural resources involved in farming activities, in directing agricultural practices towards a safer, more healthy and sustainable food production (European Commission, 2010; OECD, 2013). To this concern, a particular attention is devoted to the characterization of an environmentally sustainable farm (Merante et al., 2015).

The agricultural sector stands between the economy and environment, and it has thus been explored in both domains: on the environmental side, through methodologies based on a bio-naturalistic approach, with no interactions with the economic side (IPCC, 2006); on the economic side, using an industrial approach, where the connections between agriculture and the environment are not considered (Birkved et al., 2006; Nemecek et al., 2007). Such mono-disciplinary approaches do not consider the specific nature of agriculture, which manages plants and animals biological cycles for production purposes (Dale et al., 2013; Moss, 2000). Indeed, the relationship between agriculture and environment goes over the economic performance, despite what happens for other human activities where this latter is often considered the unique or, at least, the main goal. Farmers are the largest group of natural resource managers in the world (FAO, 2007) and they produce a wide variety of ecosystem services that are valuable for the society (Ribaudo et al., 2010).

Anthropogenic perturbations due to farming practices affect the ecosystem but sometimes may have potential positive effects (Desjardins et al., 2000). Nevertheless, an effort to minimize potential negative impacts and to promote positive effects of agricultural activities on environments is required (Liebig et al. 2007; Gan et al., 2012).

In evaluating the relationship between agriculture and environment it should be considered that farming achieves an "internalization of externalities", as the effect of its activities impact on its own productive factors (Odum & Odum, 2000). This means that, before affecting the "external" environment, the effects of farmers' environmental actions fall on (present and future) production of the farm itself. Thus, it is crucial to identify the results of farming activities on the farm ecosystem, in order to limit their negative impacts on natural resources, and to promote actions that improve ecosystems' quality.

As specified in the following section dedicated to the description of the methodology, different approaches to assess the environmental impact of agriculture have been proposed (Gerdessen and Pascucci, 2013). However, as discussed later in this paper, they show some limitations in expressing the environmental sustainability of farming activity in quantitative terms directly comparable with the related economic performances. Among such approaches, an interesting possibility is offered by the Ecological Footprint (Wackernagel and Rees, 1996), a methodology that, to be correctly applied at farm level, requires some adaptations.

The aim of this paper is thus to apply in a particular case study an innovative approach based on the Ecological Footprint (EF) methodology to evaluate the environmental impact of a crop productive system at farm level and to discuss the relationship with its economic performance.

After a brief review of the main attempts of assessing the environmental impacts of agriculture, the application of the proposed methodology in a case study is illustrated in order to provide a basis for a discussion of the environmental and economic consequences of farmers' choices. The results lead to some considerations about the need for a joint assessment of both the economic and environmental impact of farming activities to drive farmers towards more sustainable behaviours.

2. Methodology

2.1 Traditional approaches to assess the environmental impact of agriculture

The effects of agriculture on ecosystems can be evaluated from two different perspectives. A first approach looks at environmental outcomes of farming by considering either the impacts due to the input used into the cropping practices (West et al., 2002; Franzluebbers et al., 2005) or the exploitation of the natural resources embedded in the products of farming (Suh et al., 2004; Ardente et al., 2006).
A second approach is more focused on the capacity of (agricultural) ecosystems of receiving and managing the environmental impact caused by farming activities (García-Oliva et al., 2004; Fung et al., 2005; Cowie et al., 2007). Such an approach moves from the well-known concept of carrying capacity of ecosystems, which marks a limit not to be exceeded in the exploitation of ecosystems by anthropogenic activities.
These two perspectives study the relationship between agriculture and environment from an opposite standpoint – the production-caused and the ecosystem-received impacts – but they

do not take into account their complex interactions. However, this seems to be a crucial point for the understanding and assessment of the actual links between agriculture and environment. Indeed, it should be explicitly considered that, from one side, the ecosystem conditions affect the crop techniques and productions and, from the other side, the farming activities modify the supply of agro-ecosystem services.

An alternative approach able to catch such interactions is provided by Ecological Footprint Accounting (hereafter EFA). It looks at both the demand and the supply of natural resources though two metrics, namely Ecological Footprint (EF) and biocapacity (BC): the first is measured through the ecological demand from human activities, the second through the ecosystem capacity of providing ecological goods and services.

Introduced and developed by William Rees and Mathis Wackernagel (1994, 1996), EFA provides a measure of the pressure of anthropogenic activities on the planet. The calculation starts from the evaluation of the consumption of natural capital caused by human activities in a certain area, which is then compared with the flow of resource provisioning and regulatory ecological services that the natural ecosystems are able to provide in the same area (Galli et al., 2014). The EF's output is a measure of the equivalent bioproductive area demanded by the residents, rather than an assessment of the maximum human population that an area can support (Bagliani et al., 2008).

While the EF measures human demand on nature, BC tracks the supply of ecosystem services. BC is defined as the rate of resource supply and waste disposal that can be sustained in a given territory under the prevailing technologies and management schemes. Both EF and BC are measured in standard units, the global hectares (gha), where a gha represents a standardized hectare with the world average productivity (Borucke et al., 2013).

EFA methodology has been widely used to explore different issues related to the pressure on the environment of human activities (see, among others, Thomassen et al., 2005; Liu et al., 2008; Bagliani et al, 2008; Limnios et al., 2009) and, specifically, of farming (Deumling et al., 2003; Van der Werf et al., 2006; Cuandra et al., 2007; Niccolucci et al., 2008).

Nevertheless, the EFA methodology, as conceived by its creators, has been shown not to be able to catch all the implications of the agricultural activities on the EF and BC assessment (Kitzes et al., 2009). Namely, it cannot point out any under/over exploitation of natural resources originated from crop farming, due to the structure of the main equation for computing crops EF and BC (Niccolucci et al., 2008; Mozner, 2012; Passeri et al., 2013; Galli A., 2015). The consequences of such limitation have been discussed by some authors, which have highlighted how this makes the method unsuitable for agricultural policies evaluation (Ferng, 2005) and correct sustainability assessments (Fiala, 2008).

Recently, a methodological development proposed by Passeri et al. (2013) made it possible to overcome this problem by means of a different method of calculating the ecological footprint of crops. Such improvement of the EFA methodology, with specific reference to its utilization at farm level, will be briefly described in the following paragraph.

2.2 Modified EFA methodology

As pointed out in the previous paragraph, the farm-gate environmental analysis is here performed on the basis of the EFA approach but adopting an appropriate methodological development based on the concept of an embodied footprint in crop production.

This upgrade of EFA considers two separate impacts of crop management: the Ecological Footprint due to the inputs used during the crop cycle (EF_{inp}) and the Ecological Footprint generated by the overexploitation of natural land productivity (EF_{ovp}).

The EF_{inp} of a crop is evaluated as the sum of the EFs of individual inputs; these are calculated using conversion coefficients available both from published international researches, as listed in Passeri et al. (2013), and National Footprint Account (GFN, 2011).

In order to assess EF_{ovp}, it is necessary to compare the actual production of the crop (P) with the production associated with a "natural system", which in the agricultural ecosystem can be conceived as a "minimum input" cultivation technique (P_{min}). Such overproduction is defined as the productivity of the specific crop that exceeds its natural productivity (i.e. the productivity associated to the simplest crop management), due to the crop management of the farmer. It is evaluated as $\alpha=(P-P_{min}/P)$. So the EF of a crop can be calculated as follows:

$$EF = EF_{inp} + EF_{ovp} = EF_{inp} + \alpha \times \frac{P}{Yw} \times EQF$$

In this equation, according with the EF definition, Yw is the world average yield of the same product (Galli et al., 2007) and EQF (Equivalence Factor) is a scaling factor to convert a specific land-use into global hectares (Monfreda et al., 2004; Wackernagel and Rees, 1996).

Once the Footprint of the crop is calculated, it has to be compared with the ecological services provided by the crop itself, i.e. its BC. According to the Ecological Footprint traditional approach it can be calculated, for a unit area (1 ha), as (Wackernagel and Rees, 1996):

$$BC = \frac{P}{Yw} \times EQF$$

The difference between BC and EF is the Ecological Balance (EB) of the crop, which expresses the surplus (if positive) or the deficit (if negative) of natural resources associated with the crop cultivation technique in the given agricultural ecosystem.

BC, EF and EB values for each crop are then aggregated to determine the overall environmental performance at farm level.

2.3 Economic accounting of crops

Concerning the economic side of the analysis, the methodology used provides the evaluation of the individual crop budgets, expressed as gross margin and calculated as the difference between the revenues and variable costs, which are then aggregated at the farm level. Each crop budget takes into account the utilization of all the production factors as well as all the processes – e.g. farming operations – involved all along the cultivation process until the output production. Crop revenues are originated from the value of the production and the possible public payments (support provided from agricultural policies, subsidies for organic farming etc.); these latter are explicitly included into the analysis because they are considered in the farmer's management choices. Costs are calculated multiplying the quantity of each production factor for its price. They are evaluated separately for each category (raw materials, machinery, labour, other costs) and then aggregated in order to obtain the specific crop's costs.

Revenues, costs and gross margin of each crop are then aggregated to determine the overall economical performance of the crop production system at farm level.

2.4 Case study

A farm located in southern Tuscany (Italy) is here analyzed. The farm Utilized Agricultural Area (UAA) is 29 hectares (ha) and its production plan is organized on the basis of perennial crops (olive trees and vineyards) and annual crops (vegetables and cereals). The farm includes also unproductive surfaces, such as roads, buildings and small areas with natural vegetation; although the latter provide a contribution to biocapacity, they were not considered in the analysis, as their use does not fall in the farmer's choices. The farm is managed following organic and integrated farming: organic farming standard follows the related EU Regulation (Reg. CE 834/07 e Reg. CE 889/08), while the integrated management (named Integrated Pest Management – IPM) follows the guidelines provided by the European Parliament. In our analysis, we refer to the year 2013, when the cropping system was organized as follows: tomatoes (5 ha), durum wheat (5 ha), olive orchard (9 ha) and vineyards (10 ha). Tomatoes and durum wheat were cultivated under organic farming while olive orchard and vineyards followed integrated farming.

Table 1 resumes the data of the production of the four crops in the year 2013.

Table 1 – Data about crops production in 2013

Crop	*UAA [ha]*	*Production [ton]*	*Yield (P) [ton/ha]*
Durum Wheat	5	10	2.0
Tomato	5	300	60.0
Olive	9	36	4.0
Vineyard	10	80	8.0

Source: our elaboration

3. Results

According with the methodology illustrated above, for each crop the EF is evaluated as the sum of the two components EF_{inp} and EF_{ovp}.

The first component expresses the EF associated with the inputs utilized in the cultivation process. For each input the quantity is multiplied for the related impact coefficient and then the single impacts are aggregated. To do so, the embodied footprint in each input (except for labour, see Limnios et al., 2009) is calculated starting from available data expressed in terms of CO_2 emissions (Passeri et al., 2013), so it has been estimated the total amount of CO_2 emission and then it has been converted into *gha*. Table 2 shows this calculation with reference to one hectare of durum wheat.

Table 2 – Calculation of EF_{inp} of durum wheat per unit area (ha)

Input	*Quantity*	*Coefficient*	*Emissions [tonCO$_2$]*	*Yw [wha/tonCO$_2$]*	*EQF [gha/wha]*	*EF [gha]*
Seeds	121,000 *units*	1.4 E-22 *tonCO$_2$/unit*	1.7 E-17	2.58	2.51	0.000
Fertilizer (Manure)	0.3 *ton*	0.0080 *tonCO$_2$/ton*	0.0024	2.58	1.26	0.008
Pesticides	0.0 *kg*		0.0000			0.000
Fuel (used by farmer)	*92 kg*					
Fuel (used by contractor)	*47 kg*					
Fuel	139 *kg*	0.0032 *tonCO$_2$/kg*	0.4420	2.58	1.26	1.440
Labour (farmer)	*14 h*					
Labour (contractor)	*10 h*					
Labour	24 *h*	0.0005 *gha/h*				0.012
EF_{inp}						1.460

Source: our elaboration based on standard coefficients (see Passeri et al., 2013)

Following the same calculation scheme (as shown in the Appendix 1), the value of EF_{inp} for the three other crops – tomatoes, olive trees and vineyard – is respectively 4.429, 4.193 and 3.439 gha/ha.

In order to assess the EF_{ovp} component, the actual yield (P) has to be compared with the "minimum input" yield (P_{min}). This value it is not easy to determine: a specific investigation would be needed on a well-established experimental plan, with the aim to detect the crop productivity under "natural condition" in a comparable agro-ecosystem. It is evident that performing such an investigation on all the crops in all the possible agro-ecosystems is not practicable (De Ponti et al., 2012). For a first estimation of P_{min} values it has been supposed that, even if in some cases an organic technique requires more inputs than a conventional one, a low input organic farming management is sufficiently similar to the agronomic condition associated with the "minimum input" productivity level. According to this hypothesis, the P_{min} values for the four crops have been provided by an analysis carried out on Tuscany's organic farms data collected in FADN database (RICA, 2014). Therefore, considering the crops world yield (Yw) and the equivalence factor (EQF), both available from GFN (2011), it is possible to evaluate the EF_{ovp} component and, by adding up the two components, the total EF.

From the same data, by applying the BC equation, it is possible to calculate the supply of ecosystem services by each crop (Table 3).

Table 3 – Calculation of crops' EF_{ovp}, EF, BC and EB

	Wheat	*Tomato*	*Olive*	*Vineyard*
P *[ton/ha]*	2.0	60.0	4.0	8.0
P_{min} *[ton/ha]*	2.0	50.0	3.5	5.0
α	0.000	0.167	0.125	0.375
Yw *[ton/ha]*	2.35	27.29	1.48	7.46
EQF *[gha/ha]*	2.51	2.51	2.51	2.51
EF_{ovp} *[gha/ha]*	0.000	0.920	0.848	1.009
EF_{inp} *[gha/ha]*	1.460	4.429	4.193	3.439
EF *[gha/ha]*	1.460	5.349	5.041	4.448

BC *[gha/ha]*	2.136	5.519	6.784	2.692
EB *[gha/ha]*	+0.676	+0.170	+1.743	-1.756

Source: our elaboration based on standard coefficients (GFN, 2011)

Next we calculated the economic performances of the crops by considering the gross margin, defined as the difference between revenues and direct costs. Among the revenues, the agro-environmental subsidies were also considered; their amount was calculated as the average payment per hectare got by the farm. Table 4 shows the calculation process and the result for durum wheat.

Table 4 – Calculation of gross margin of durum wheat (data per ha)

Input	*Quantity*	*Price*	*Value (€/ha)*
Product I – Wheat *[ton]*	2.0	382	764
Product II – Hay *[ton]*	4.0	30	120
Agro-environmental subsidies *[€]*			150
Revenues *[€]*			**1,034**
Seeds *[ton]*	2.0	57.50	116
Fertilizer *[ton]*	0.3	0.00	0
Pesticides *[€]*	0		0
Fuel (used by farmer) *[kg]*	92	1.58	145
Labour (provided by farmer)*[hour]*	14	15.00	210
Contractor *[€]*			260
Other costs *[€]*			34
Variable Costs *[€]*			**764**
Gross margin *[€]*			**270**

Source: our elaboration

Following the same procedure, as shown in the Appendix 2, the gross margin for the other three crops was calculated: 1,805 €/ha for tomatoes, 205 €/ha for olive trees, 400 €/ha for vineyard.

The aggregation of single crop results (table 5) provides an assessment of the environmental and economic performances of the farm cropping system.

Table 5 – Ecological and economic results at the farm level

Crop	*UAA [ha]*	*EF [gha]*	*BC [gha]*	*EB [gha]*	*Revenues [€]*	*Costs [€]*	*Gross Margin [€]*
Wheat	5	7.30	10.68	+3.38	5,170	3,820	1,350
Tomato	5	26.75	27.60	+0.85	30,450	21,425	9,025
Olive	9	45.37	61.06	+15.69	29,160	27,315	1,845
Vineyard	10	44.48	26.92	-17.56	59,500	55,500	4,000
Total	29	123.89	126.25	+2.36	124,280	108,060	16,220

Source: our elaboration

4. Discussion

The farm cropping system shows an overall positive ecological balance. This result arises from two crops (olive and wheat) that provide a net supply of resources and one crop (vineyard) expressing a net ecological demand. However, the positive ecological balance of wheat is mainly due to a low EF, while the same result for olive is due to its high BC. The fourth crop (tomato) is in equilibrium between EF and BC.

In general, for all the crops, the contribution of EF_{inp} is the most important component of Ecological Footprint, a result that originates mainly from the fuel burned in machinery operations, which accounts for 70-80% (almost the 100% for the durum wheat) of the whole environmental impact of cultivation techniques. The explanation of such evidence is twofold. On the one hand, it is due to the overall lower yield that characterizes the organic production, which limits the role of overproduction in determining the total EF. On the other hand, again considering the crops' organic management, the fertilizers and pesticides utilization is generally less intensive and hence their environmental impact is marginal.

Looking at the economic results, it is evident that the largest part of the gross margin (more than 80%) is originated by tomato and vineyard, while the contribution of durum wheat and olive trees is very limited. It follows that the crops with the lower environmental performances sustain the farm income, while the crops with a largely positive value of ecological balance have a marginal contribution in farm profitability.

To this regard, it is interesting to note that the economic-environmental trade-off shows a mutual relationship within perennial and annual crops. In fact, among farm orchards, the high biocapacity of olive trees is able to compensate the exceeding EF of vineyards, and, at the same time, the ecological balance surplus of durum wheat could guarantee the possible overexploitation of natural resource caused by a more intensive use of inputs in tomatoes cultivation. This situation can be understood as a sort of balance, both from the economic and the environmental point of view, between a short and a mid-long term perspective.

Moreover, it emerges that the high-profitability crops (vineyard and tomato) are environmentally sustained by low-profitability crops (olive trees and wheat). It suggests that such cropping mix (typical of small-medium farms in Mediterranean area) limits the risk linked to agricultural markets price volatility and, at the same time, demands an amount of environmental resources that doesn't exceed their supply at farm level.

The results confirm that in farms cultivation patterns a single crop should be considered not only for its specific production, but also for its role within the complex farm organization both from the economic and the ecological point of view. It follows that good farm management is a complex balance between environmental and economic issues and it has to be pursued paying attention at the same time to the production of marketable goods and the integrity of natural capital. This requires a systemic approach to cropping systems management because the farm performances are affected both by economic and non-economic factors (Tellarini et al., 2000).

To this perspective, performing the environmental-economic analysis at farm level emphasizes the role of the farmers as agro-ecosystem managers, who should promote the best integration of the ecological attitudes of their land to the economic implications of their choices (Calker et al., 2004).

5. Conclusions

In this paper an innovative approach based on the Ecological Footprint accounting was used to assess the sustainability of a cropping pattern and to evaluate and analyse the trade-offs between environmental and economic performances.

This methodology relates to the environmental impact of each crop in the farm cultivation system – calculated taking into account the inputs used and the overexploitation of the soil productivity – with the biocapacity that the same crop is able to provide. The ecological balance obtained by this comparison can be compared with the crops economic results in order to highlight the relationship between these two dimensions.

Such methodology was applied in a case study farm and the results offer interesting insights about the economic-environmental relationship at farm level. The cropping system of the farm showed an overall positive ecological balance (+2,4 gha) and a gross margin of 16,200 €. The trade-off among the environmental and economic dimensions is evident: the crops with the worst environmental performances sustain the farm income, while the crops with a positive ecological balance bring a very limited contribution to the economic profitability.

However, beyond the specific figures obtained, a key point that emerges is the need to consider and analyse the farm as a whole. In fact, both the economic and the environmental sustainability can only be ensured through an appropriate combination of different crops, in both the short and long run. In general, high profitability crops are resources consuming (which, in our assessment, means unsustainable) while those that provide a positive ecological balance have low gross margins.

So, a well-suited crop mix should balance the search for the higher economic performances with a positive ecological balance at the farm level. This evidence suggests approaching a cropping pattern in a systemic perspective, explicitly considering the interrelations between its economic and environmental dimensions.

From this perspective, the farmer is no longer an economic agent whose aim is to maximize its profit trying to limit the negative externalities of production processes, but rather a caretaker of natural resources intended for agricultural production and income generation.

The implications of this study, beyond its intrinsic limitation due to the case sensitiveness of the analysis, can stimulate new reflections on the peculiar role of farmers.

Such reflections should be considered, for example, in addressing agro-environmental policies, which look at the farmer as one of the main actors of natural resources preservation. Indeed, the possibility of assessing the relationships between economic choices and resources consumption/savings at farm level could help in implementing more effective policies able to increase farmers' revenues reducing at the same time the environmental impacts of agricultural systems.

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Author' contribution

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Appendix 1

Calculation of EF_{inp} of tomatoes per unit area (ha)

Input	*Quantity*	*Coefficient*	*Emissions [tonCO$_2$]*	*Yw [wha/tonCO$_2$]*	*EQF [gha/wha]*	*EF [gha]*
Seeds	121,000 *units*	1.4 E-22 *tonCO$_2$/unit*	1.7 E-17	2.58	2.51	0.000
Fertilizer (Manure)	*400 kg*	0.008 *kgCO$_2$/kg*	*0.0032*	2.58	1.26	*0.010*
Fertilizer (N)	*21 kg*	3.750 *kgCO$_2$/kg*	*0.0795*	2.58	1.26	*0.259*
Fertilizer (P)	*22 kg*	0.065 *kgCO$_2$/kg*	*0.0014*	2.58	1.26	*0.005*
Fertilizer (K)	*38 kg*	0.037 *kgCO$_2$/kg*	*0.0014*	2.58	1.26	*0.005*
Fertilizer			0.0855			0.279
Pesticides (Fungicide)	20 *kg*	0.0292 *kgCO$_2$/kg*	0.0001	2.58	1.26	0.002
Fuel (used by farmer)	*245 kg*					
Fuel (used by	*144 kg*					

contractor)						
Fuel	399 *kg*	0.0032 *tonCO$_2$/kg*	1.2641	2.58	1.26	4.117
Labour (farmer)	*32 h*					
Labour (contractor)	*26 h*					
Labour	58 *h*	0.0005 *gha/h*				0.032
EF_{inp}						4.429

Source: our elaboration based on standard coefficients (see Passeri et al., 2013)

Calculation of EF_{inp} of olive trees per unit area (ha)

Input	*Quantity*	*Coefficient*	*Emissions [tonCO$_2$]*	*Yw [wha/tonCO$_2$]*	*EQF [gha/wha]*	*EF [gha]*
Fertilizer (N)	*30 kg*	3.750 *kgCO$_2$/kg*	*0.1125*	2.58	1.26	*0.366*
Fertilizer (P)	*9 kg*	0.065 *kgCO$_2$/kg*	*0.0006*	2.58	1.26	*0.002*
Fertilizer (K)	*9 kg*	0.037 *kgCO$_2$/kg*	*0.0003*	2.58	1.26	*0.001*
Fertilizer			0.0855			0.369
Pesticides (Insecticide)	25 *kg*	0.0189 *kgCO$_2$/kg*	0.0005	2.58	1.26	0.002
Fuel (farmer)	*47 kg*					
Fuel (contractor)	*315 kg*					
Fuel	362 *kg*	0.0032 *tonCO$_2$/kg*	1.1494	2.58	1.26	3.743
Labour (farmer)	*14 h*					
Labour (contractor)	*130 h*					
Labour	144 *h*	0.0005 *gha/h*				0.079
EF_{inp}						4.193

Source: our elaboration based on standard coefficients (see Passeri et al., 2013)

Calculation of EF_{inp} of vineyard per unit area (ha)

Input	*Quantity*	*Coefficient*	*Emissions [tonCO$_2$]*	*Yw [wha/tonCO$_2$]*	*EQF [gha/wha]*	*EF [gha]*
Fertilizer (N)	*13 kg*	3.750 *kgCO$_2$/kg*	*0.0469*	2.58	1.26	*0.153*
Fertilizer (P)	*29 kg*	0.065 *kgCO$_2$/kg*	*0.0019*	2.58	1.26	*0.006*
Fertilizer (K)	*3 kg*	0.037 *kgCO$_2$/kg*	*0.0001*	2.58	1.26	*0.000*
Fertilizer			0.0489			0.159
Pesticides (Fungicide)	80 *kg*	0.0292 *kgCO$_2$/kg*	0.0024	2.58	1.26	0.008
Fuel (farmer)	*214 kg*					
Fuel (contractor)	*92 kg*					
Fuel	306 *kg*	0.0032 *tonCO$_2$/kg*	0.9720	2.58	1.26	3.166
Labour (farmer)	*52 h*					
Labour (contractor)	*160 h*					
Labour	212 *h*	0.0005 *gha/h*				0.106

EF_{inp}	3.439

Source: our elaboration based on standard coefficients (see Passeri et al., 2013)

Appendix 2

Calculation of gross margin of tomatoes (data per ha)

Input	*Quantity*	*Price*	*Value (€/ha)*
Product I – Tomatoes *[ton]*	60.0	95	5,700
Agro-environmental subsidies *[€]*			390
Revenues *[€]*			**6,090**
Seeds *[ton]*	3.5	250.00	875
Fertilizer *[€]*			1,510
Pesticides *[€]*			156
Fuel (used by farmer) *[kg]*	245	1.58	387
Labour (provided by farmer)*[hour]*	32	15.00	480
Contractor *[€]*			650
Other costs *[€]*			227
Variable Costs *[€]*			**4.285**
Gross margin *[€]*			**1.805**

Source: our elaboration

Calculation of gross margin of olive trees (data per ha)

Input	*Quantity*	*Price*	*Value (€/ha)*
Product I – Olives *[ton]*	4.0	760	3,040
Agro-environmental subsidies *[€]*			200
Revenues *[€]*			**3,240**
Fertilizer *[€]*			1,260
Pesticides *[€]*			145
Fuel (used by farmer) *[kg]*	47	1.58	74
Labour (provided by farmer)*[hour]*	14	15.00	210
Contractor *[€]*			1,300
Other costs *[€]*			46
Variable Costs *[€]*			**3.035**
Gross margin *[€]*			**205**

Source: our elaboration

Calculation of gross margin of vineyard (data per ha)

Input	*Quantity*	*Price*	*Value (€/ha)*
Product I – Olives *[ton]*	8.0	70	5,600
Agro-environmental subsidies *[€]*			350
Revenues *[€]*			**5,950**
Fertilizer *[€]*			1,076
Pesticides *[€]*			562
Fuel (used by farmer) *[kg]*	214	1.58	338
Labour (provided by farmer)*[hour]*	52	15.00	780
Contractor *[€]*			2,400
Other costs *[€]*			394
Variable Costs *[€]*			**5.550**
Gross margin *[€]*			**400**

Source: our elaboration