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Assessing the environmental sustainability of local agricultural systems: How and why

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ABSTRACT

This paper focuses on the quantitative assessment, on a local scale, of the environmental sustainability of agricultural activities. To compare the supply and demand of natural resources in a local agricultural system, a methodology based on the ecological footprint approach was adopted. The condition of (strong) sustainability of an agricultural system is established through an ecological balance where the availability of natural capital, expressed in terms of biocapacity (BC), is compared to its demand by agricultural activities, expressed as ecological footprint (EF). The viability of this methodology was tested in the agricultural area of Viterbo municipality (central Italy).

The results of this study provide interesting points of departure for further research regarding the possibility of defining an agricultural production system as "sustainable" and of introducing a regional sustainability brand as a key for local development.

1. Introduction

The study of the environmental sustainability of agricultural activities has long been a subject of interest for scholars and its importance and popularity currently show no signs of waning. The extensive literature dealing with this topic can be divided into different strands: (i) the object of the study, (ii) the methods and indicators used, and (iii) the purpose of the studies.

As regards the object (i), a fairly clear differentiation can be observed; environmental sustainability in the agricultural sector can refer to products, processes, farms, supply chains and, as is the case of this study, specific areas. As for methodologies (ii), and their indicators, the literature on environmental sustainability is very wide-ranging. Among the many reviews carried out in the last twenty years, the following may be cited: McCool and Stankey (2004), Ness et al. (2007), Moldan et al. (2012), Singh et al. (2012), Waas et al. (2014), Dizdaroglu (2017). In terms of the purposes (iii) for which a study on the environmental sustainability of agricultural activity is being conducted, two main objectives, in addition to the theoretical-methodological one, can be distinguished even if they are not always explicitly mentioned. On the one hand, there are studies that intend to provide deeper knowledge to guide public interventions (based on agricultural or local development policies) towards a reduction in the impact of agricultural activities on natural resources (Pacini et al., 2004; Dominguez Gómez and Relinque, 2014; Paolotti et al., 2019). On the other hand are studies looking at environmental sustainability as a possible "brand" that, if properly declared and communicated to consumers, can characterize agro-food products by increasing their perceived value (Reisch et al., 2013; Grunert et al., 2014; Franco and Cicatiello, 2018).

Within such a broad and diversified framework, this paper focuses on the environmental sustainability of agricultural activities on a local scale, adopting the ecological footprint methodology (Wackernagel and Rees, 1996) and looking at the results of the analysis in a perspective able to guide local environmental and development policies. In the first part of the paper, the definition of environmental sustainability of a region is discussed, with particular reference to its agricultural activities, and the use of ecological footprint as a methodology to assess sustainability. The positive implications of a sustainable agricultural system on local economic development are also highlighted. The second part describes the methodology used to assess the sustainability of a local agricultural system within a given region. In the third part of the paper a case study based on the environmental sustainability assessment of an Italian municipality agricultural system is presented. The paper ends with some final remarks concerning a discussion about the limits of the study, possible developments of the methodology and some observations concerning sustainability and policy implications.

2. Background

2.1. Defining a region as "sustainable": How to do it

In recent decades the concept of sustainability has gained considerable attention in many sectors of contemporary society and the use of the terms

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"sustainability" and "sustainable" has become more widespread. This has led to a general ambiguity over the definition of sustainability, a concept that nowadays can easily be adapted to a broad range of contexts and situations; this is true in general (see, for example, the reviews by Mebratu (1998) and Bolis et al. (2014)), and with regard to the agricultural sector (Velten et al., 2015). However, when taking a scientific approach with an economic perspective, the definition of sustainability narrows to a quality that can characterize a specific object through the attribute of being "sustainable".

To verify the effectiveness of this attribute for a certain object, some key conditions must be met (Rennings and Wiggering, 1997): (i) an unambiguous definition of sustainability; (ii) one (or more) indicator(s) able to translate such a definition in operative terms; (iii) the possibility of correctly assessing this (these) indicator(s) with reference to the object under consideration.

As regards the first condition, the economic approach to the concept of sustainability focuses on natural capital - i.e. the range of functions provided by the natural environment (Ekins et al., 2003) – distinguishing between two different positions: strict preservation or the possible substitution with man-made capital. These two alternatives mark the difference between strong and weak sustainability paradigms (Dietz and Neumayer, 2007). Strong sustainability requires the natural capital to be preserved in physical terms, so that its functions remain intact (Barbier and Burgess, 2017). Every analysis aimed at establishing a sustainability condition needs to refer to an assessment of natural capital availability and its exploitation by economic activities. The indicators that can be used to carry out such an assessment are many and the literature on this topic is extensive (see, among others, McCool and Stankey, 2004; Hezri and Dovers, 2006; Moldan et al., 2012; Singh et al., 2012). Among them, one of the most popular is the ecological footprint (Wackernagel and Rees, 1996). Indeed, in line with the principles of sustainability (Daly, 1992), the ecological footprint methodology is able to take account of the supply and demand of the natural resources a community requires to support its activities (Mancini et al., 2017).

The ecological footprint approach establishes the sustainability of a region by assessing an indicator, named the Ecological Footprint (EF), which measures the equivalent biologically productive area required to produce the renewable resources and ecological services exploited by human activities that take place in such an area. This value should be related to BioCapacity (BC), the indicator that tracks the ecological assets available in a region and their capacity to produce renewable resources and ecological services (Galli et al., 2014; Mancini et al., 2017). The comparison between BC and EF produces the indicator named Ecological Balance (EB), which represents the environmental surplus/deficit of a region. EB expresses the notion of carrying capacity in terms of land area by translating economic activity into the area required to produce the resources consumed and to assimilate the waste generated by a given region. (Neumayer, 2013). This is the reason why many scholars agree that the ecological footprint is a coherent approach to assess (strong) sustainability (Dietz and Neumayer, 2007; Monfreda et al., 2004; Mori and Christodoulou, 2012; Huang, 2018). In particular, it can be applied at a local level to evaluate regional sustainability (Graymore et al., 2008; Graymore et al., 2010; Knaus et al., 2006; Scotti et al., 2009; Wackernagel and Yount, 1998; Wilson and Grant, 2009).

The ecological footprint methodology for sustainability assessment can also be applied to a single economic sector within a region, namely the agricultural sector, evaluating its specific resource consumption (measured by EF) and supply (expressed by the associated BC). Once an agricultural system has been spatially defined, EF is represented by the bio-productive area required to support the production activities carried out by the local farms as a whole; BC is determined by the biocapacity supplied by the total amount of farmland in the region (Loiseau et al., 2012; Ghosh and Chakma, 2018).

There are numerous studies that have addressed the assessment of sustainability in agriculture, with particular reference to crops, in various countries: China (Li et al., 2020; Xun and Hu, 2019; Wang et al., 2019; Bai et al., 2015), India (Ghosh and Chakma, 2018), Italy (Blasi et al., 2016; Passeri et al., 2016) and Nicaragua (Cuadra and Björklund, 2007). In the study presented in this paper, the environmental sustainability of the agricultural system of the Viterbo municipality (central Italy) is assessed.

2.2. Defining a region as "sustainable": Why do it?

Agriculture, and more generally food production processes, have a major global environmental impact on biodiversity, greenhouse gas emissions and pollution due to fertilizers, other external inputs and agricultural practices (Tilman et al., 2011). Consequently, the demand for food whose production has a limited impact on the environment is growing rapidly, together with the spread of sustainability-related information about food. According to a survey developed by Nielsen (www.nielsen.com) in 2015, involving 30,000 respondents in 60 countries, consumers' food choices are highly influenced by sustainability-related issues. At the same time, consumers are increasingly exposed to labels, logos and messages which convey the environmental and ethical values of food products, providing clear information on the processes of all the food production chain. The literature on the concept of sustainability in the food sector is abundant; an exhaustive review on this topic can be found in Gruner (2011) and, more recently, in Bollani et al. (2019).

From a marketing perspective, sustainability can be conceived as a form of branding, which is linked to a product having a (or a set of) credence attribute(s). Indeed, when a product carries with it an idea of sustainability, consumers assign a credence attribute to the product, according to the extent to which they understand and share such an idea (Verain et al., 2012; Palmieri and Perito, 2020). So, similarly to other brands, a "sustainability-related" brand starts to take shape and its incorporated value influences the consumer's perception of quality and choices (Franco and Cicatiello, 2018). A key concern of food marketing should focus on the effects of sustainability branding on consumers' attitudes and their intention to buy the product. These effects are: to stimulate consumer interest in purchasing the product; to increase consumer willingness to pay for the product; to raise consumer satisfaction of the purchase and consumption; to establish a long-term relationship with the consumer, resulting in customer loyalty to the sustainability brand (Bartels and Hoogendam, 2011).

In considering these effects, an important issue in the food sector is the so-called attitude-behaviour intention gap. This is the presumed gap existing between a favourable attitude towards sustainable behaviours and the actual intention to purchase sustainable food products (Vermeir and Verbeke, 2006). Indeed, although general interest in sustainability is increasing, and consumer attitude towards sustainable behaviour can be considered positive, the actual purchase behaviour is not univocally consistent with such an attitude. Vermeir and Verbeke (2006) demonstrated that attitude towards buying sustainability branded products is positively affected by both the individual involvement with sustainability and the degree of certainty regarding sustainability claims.

The main tools available for this purpose are sustainability labels on food products, as they allow consumers to consider the environmental and ethical impact of a product while making food choices (Grunert et al., 2014). However, informing consumers on product sustainability does not imply that they will actually prefer them; it depends on their motivation for sustainability and on whether they understand the meaning of the labels themselves, recognizing the kind of sustainability they care about (Grunert et al., 2014). It follows that the presence of a sustainability label on food products expands the attributes considered by consumers in food choices, especially when consumers are motivated and have an understanding of the issues. The presence of both motivation and understanding in the consumer's mind determines their awareness of a sustainability brand, which is the necessary premise for sustainability to be integrated into the food purchase choices.

Considering the intrinsic territorial nature of agro-food products, the idea that an agricultural system can be declared sustainable using an easily understandable and communicable evaluation scheme can significantly contribute to increasing consumers' motivation and understanding. The possibility of characterising local products with a regional eco-label (Jad'ud'ová et al., 2020) can generate a virtuous circle that increases consumer satisfaction, leads producers towards production methods with a lower environmental impact and promotes an effective sustainable development of the whole region.

From a more general perspective, the growing attention towards sustainability in the agri-food sector from public institutions, and in particular the European Union, cannot be ignored. The European Green Deal (European Commission, 2019) and the Farm to Fork strategy (European Commission, 2020) confirm that environmental sustainability of agricultural production has become a key issue in the agenda of policy makers. In this regard, the possibility of assessing the sustainability of an agricultural system, both at farm level or on a regional scale, can provide important indications to assist the design of a policy framework able to achieve compatibility between agricultural activities and environmental priorities (Passeri et al., 2016).

3. Methodology

3.1. Sustainability assessment of agricultural systems

The process adopted to assess the condition of sustainability of a local agricultural system through the ecological footprint approach is summarised in Fig. 1.

This process is based on three main steps.

1. Evaluation of total biocapacity (BC_{TOT}), based on the different land types within the agricultural area of the region: crop land under agricultural production (BC_C), and other bioproductive areas – forest land, grazing land, built-up land, other arable land – (BC_A).
2. Evaluation of the total ecological footprint (EF_{TOT}), caused by the different production processes (crops and livestock) and other management tasks directly linked to agricultural activity.
3. Calculation of the ecological balance ($EB = BC_{TOT} - EF_{TOT}$), which represents the value of the synthetic indicator able to establish the local agricultural system sustainability.

3.2. Calculation of biocapacity

As shown in Fig. 1, and according to the standard ecological footprint approach, four land types contribute to biocapacity: crop, forest, grazing and built-up land. Starting from the agricultural census data, the total land given over to farms located in the region can be calculated. From the same source, the total crop, grazing and forest land can be derived, while the built-up land is the remaining area after subtracting crop, grazing, and forest land from total land. Total crop land can be divided in two parts: land under crops and arable land which is temporarily fallow, or for mixed production, such as family gardens.

The biocapacity associated with the agricultural land is evaluated applying the ecological footprint standard methodology. The area of each land type, expressed in hectares (ha), is converted into biocapacity, expressed in global hectares (gha), by applying two conversion factors: the yield factor (YF), based on the ratio between the local average yield of each land type (Yn) and the corresponding world average yield (Yw), and the equivalence factor (EQF), a scaling factor that converts one hectare of world-

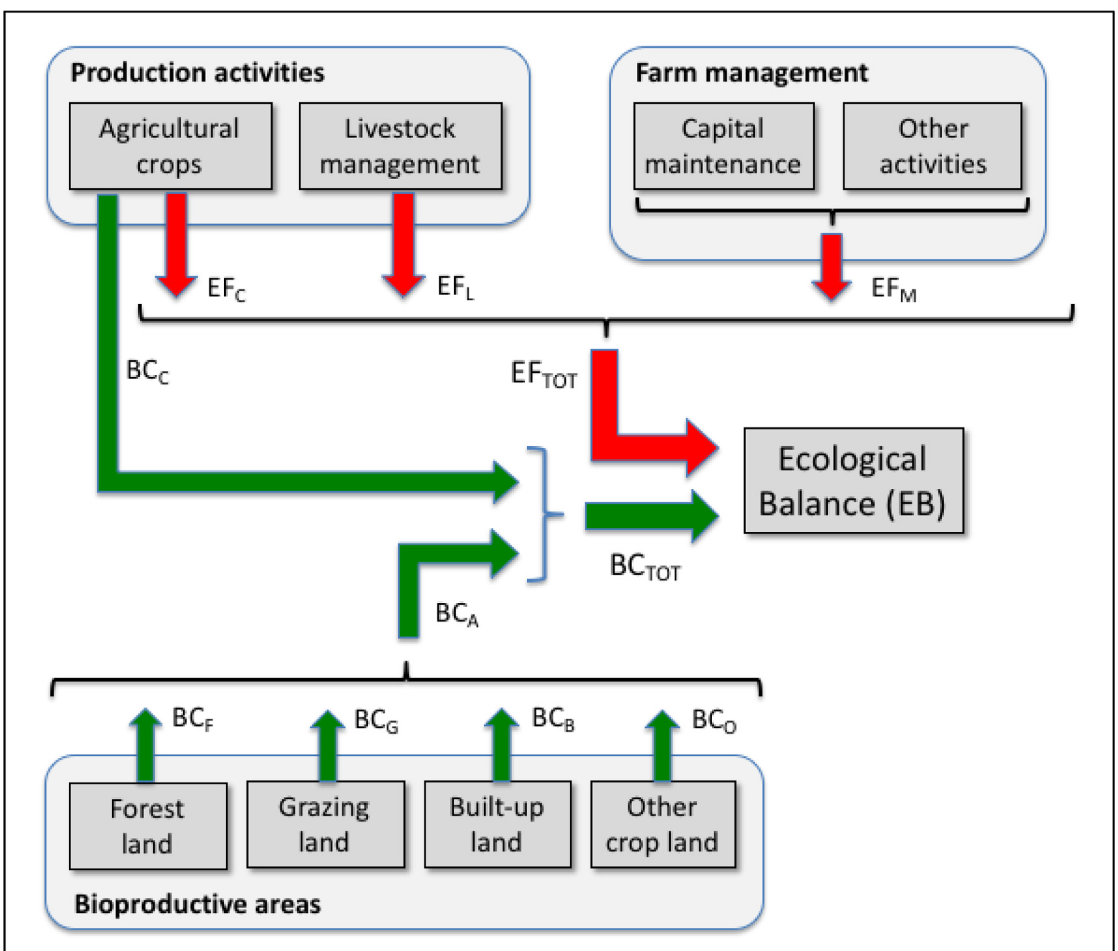

Fig. 1. Outline of the process for the assessment of agricultural systems sustainability.

average land into an equivalent number of global hectares (Wackernagel and Rees, 1996).

For forest, grazing, and built-up land, three single YF (Yn/Yw) and EQF can be considered to determine the BC_F, BC_G and BC_B components of the total biocapacity. In contrast, for crop land, the local and world average yield is different for each cultivation. It implies that the average productivity of all the crops present in the considered region should be evaluated on the base of available data (Blasi et al., 2016); in the EU, for example, the FADN (*Farm Accountancy Data Network*) can be used to gather such information. Aggregating the biocapacity of all the crops, the BC_C component can be determined. The contribution to biocapacity from crop land not under a specific crop (BC_O) is calculated using the local average crop land productivity.

3.3. Calculation of ecological footprint

Fig. 1 shows that the total ecological footprint of the local agricultural system consists of three components generated from crop production, livestock management and other farming activities. For the calculation of the EF_C associated with cultivation activities, the methodology proposed by Passeri et al. (2013) can be used. It evaluates the EF of each crop as the sum of two components, the first linked to the inputs used in the process (EF_{inp}) and the second derived from the soil overexploitation (EF_{ovp}) due to the increase in productivity compared to the hypothetical yield attainable in "natural conditions", i.e. when no human intervention, except for harvesting, is provided.

To calculate the first component, technical coefficients of the crop production processes must be derived, concerning, in particular, fertilisation, pest management, irrigation, farm machine utilisation and labour. Once this data is available, the EF_{inp} for each crop present in the region can be evaluated. For the component related to overproduction, the observed crop yield needs to be compared with that obtainable under a minimum or no inputs technique, which can be evaluated as proposed in Passeri et al. (2016); on the basis of these two values, the EF_{ovp} for each crop can be determined. Then, multiplying the ecological footprint of each crop ($EF = EF_{inp} + EF_{ovp}$), expressed in gha/ha, for the area under the crop itself within the region and adding all these results, the EF_C is obtained.

For the ecological footprint of livestock, only the component relating to the GHG emissions of the animals has to be assessed, having already included in EF_C the impact of the crops cultivated for their feed. Therefore, the EF_L component can be calculated according to the following steps:

1. collection of data on CH_4 and N_2O emissions (due to enteric fermentation and manure management) of individual types of animals (IPCC, 1997);
2. conversion of emissions calculated in step 1 in terms of carbon dioxide-equivalent (CO_2-eq) emissions (tons/head per year);
3. evaluation of total CO_2-eq emissions in the region due to livestock, calculated considering the total heads for each type of animal;
4. conversion of total CO_2-eq emissions in terms of ecological footprint according to Mancini et al. (2016).

The ecological footprint of farm activities that are not directly associated with crops and livestock management is mainly due to machinery utilisation; if this data is not available, it can be derived by subtracting the number of hours employed for crops and livestock management from the total amount for farm machine utilisation. Once this data is estimated for one hectare, it can be expanded to the entire territory and translated in terms of EF_M using the appropriate conversion factors.

4. Sustainability assessment of the agricultural system of Viterbo municipality

Viterbo is a small town of about 60,000 inhabitants located in central Italy 80 km north of Rome. The territory of the Viterbo municipality is mainly hilly; it covers an area of 40,620 ha at 300 m a.s.l. It has a strong agricultural tradition and the local agro-food sector is quite dynamic, with some quality typical products that are mainly sold on the local market, despite appreciation for these products.

Data from the last census records total agricultural land of 27,300 ha and about 2500 farms (ISTAT, 2011). The principal cultivations are cereals, mainly durum wheat and barley, olive trees for oil production, clover and alfalfa. As for livestock, the most important are sheep and poultry; in addition, the breeding of rabbit, which is one of the best known typical products, is also worth mentioning.

4.1. Calculation of BC_{TOT}

Table 1 reports data and results of the biocapacity assessment of the Viterbo municipality agricultural system. For each land type - built-up, grazing, forest and crop (2) - the total area was obtained by processing the most recent census data (ISTAT, 2011), while the conversion factors (YF and EQF) were extracted from the Global Footprint Network database (GFN, 2020).

Regarding the biocapacity associated with single crops, indicated in the table as "crop land (1)", the total value was obtained considering the contribution of each crop; this was calculated considering YF as the ratio of the average local yield (Yn), calculated using the Italian FADN database (CREA, 2020), to the world yield (Yw) available in the FAOSTAT database (FAO, 2020). The value of BC, expressed in gha/ha, is reported in the second column of Table 2.

4.2. Calculation of EF_{TOT}

To assess the EF_C component within the total ecological footprint of the local agricultural system, the area under each crop present in the municipality was assessed (ISTAT, 2011). Then, the average technical coefficients of the crop production processes were calculated using the Italian FADN databases (CREA, 2020). In particular, with reference to one hectare of each cultivation, the following coefficients were calculated:

- Amount of fertilizer, in terms of principal active ingredients (N, P, K);
- Amount of pesticides, divided in fungicides, insecticides and herbicides;
- Amount of water and electricity (only for irrigated crops);
- Hours of farm machinery utilisation;
- Hours of labour;
- Yield;
- Minimum input yield.

These coefficients were entered in an Excel spreadsheet, to obtain the EF_{inp} and EF_{ovp} values. The sum of these two components for each crop considered is recorded in the third column of Table 2.

In the same table the ecological balance (EB) of each crop on a one-hectare base and its contribution to the total value of BC_C (48,004 gha) and EF_C (37,305 gha) are presented.

To evaluate the ecological footprint of livestock in this area, the first step, as described in the methodology, was the quantification of carbon dioxide-equivalent emissions for each type of farm animal. The first two columns of Table 3 give the CH_4 and N_2O emission per head (Coderoni and Bonati, 2013), while the third column shows the corresponding amount in terms of CO_2-eq emissions. Multiplying these last figures for the related head number in Viterbo municipality area (ISTAT, 2011) the total carbon footprint of livestock can be obtained (37,418 tons CO_2-eq per year).

Table 1
Biocapacity assessment based on different land types.

	Built-up Land	Grazing Land	Forest Land	Crop Land (2)	Crop Land (1)	Total
Area (ha)	1632	2366	3637	596	19,062	27,294
YF	0.679	1.908	1.679	0.679		
EQF	2.493	0.458	1.276	2.493		
BC (gha)	2765	2069	7790	1010	48,004	61,637

Source: our elaboration on ISTAT (2011), CREA (2020) and GFN (2020) data.

Table 2
BC and EF assessment for crops of Viterbo agricultural system.

Crop	*Area (ha)*	*BC (gha/ha)*	*EF (gha/ha)*	*EB (gha/ha)*	*Total BC (gha)*	*Total EF (gha)*
Durum wheat	2728	2.50	1.48	1.02	6807	4030
Wheat	403	2.98	1.61	1.37	1200	647
Barley	1149	3.01	1.83	1.18	3460	2101
Corn	366	8.50	5.91	2.58	3107	2162
Oats	145	2.21	1.53	0.68	320	221
Other cereals	125	2.66	1.67	0.99	333	209
Legumes	123	3.13	3.04	0.09	387	376
Potato	50	3.46	3.87	−0.42	174	195
Tobacco	207	2.75	0.66	2.09	570	137
Other industrials	369	2.06	0.52	1.54	761	192
Tomato	43	3.14	4.43	−1.28	134	188
Other vegetables	347	1.36	2.94	−1.58	472	1020
Alfalfa	1927	1.71	1.17	0.54	3299	2256
Other forages	7501	1.90	1.47	0.43	14,241	11,015
Vineyards	270	1.89	2.79	−0.90	511	753
Olive trees	2472	3.84	3.55	0.30	9501	8771
Hazelnut	268	5.45	3.85	1.60	1458	1031
Chestnut	333	1.39	1.70	−0.32	462	568
Kiwifruits	69	2.03	2.93	−0.90	141	204
Other tree crops	168	2.04	2.93	−0.90	342	493
Set aside	359		0.10			37
Other crops	238	1.36	2.94		324	700
Total	19,659				48,004	37,305

Source: our elaboration on ISTAT (2011), CREA (2020) and GFN (2020) data.

To convert the carbon footprint into ecological footprint, the approach proposed by Mancini et al. (2016) was adopted. This methodology, consistent with the basic ecological footprint framework (Wackernagel and Rees, 1996), is based on the idea of quantifying the bioproductive area able to capture and stock the quantity of carbon associated with the amount of CO_2-eq emissions.

Considering that the average capacity of carbon sequestration of one hectare of forest is equal to 0.730 tons/year (Mancini et al., 2016), which corresponds to 2.677 tons CO_2-eq per year, it can be estimated that, on average, it takes 0.374 ha of forest to sequester one ton of CO_2 emissions. This figure was then converted to global hectares, taking into consideration the related equivalent factor (EQF = 1.276 gha/ha; GFN, 2020). Applying this coefficient to the value previously calculated, the ecological footprint of livestock in the local agricultural system is EF_L = 17,978 gha.

To determine the component of EF_{TOT} associated with farm activities not directly linked to agricultural production processes, an analysis based on FADN data was carried out (CREA, 2020). More specifically, for farms located in the municipality of Viterbo included in the FADN database, the difference between the total use of machinery and labour and the sum of machinery and labour used in the single production process was evaluated. The average of all these differences amounts to about 60 h/ha of labour, 15 of which carried out using machinery. These activities generate an ecological footprint of 0.113 gha/ha that, multiplied by the total area of the agricultural system (27,294 ha), produces a total EF_M of 3084 gha.

Table 4
Ecological balance of Viterbo municipality agricultural system.

Biocapacity	gha	Ecological Footprint	gha
Built-up Land	2765	Crops	37,305
Grazing Land	2069	Livestock	17,978
Forest Land	7790	Other activities	3084
Crop Land (2)	1010	**Total**	**58,367**
Crop Land (1)	48,004		
Total	**61,637**	**Ecological Balance**	**+3270**

Source: our elaboration.

4.3. Ecological balance

Table 4 collects all the data needed to provide the ecological balance of the Viterbo municipality agricultural system. In the left column of the table all the contributions to the total biocapacity BC_{TOT}, which is 61,637 gha, have been summarised. In the right column the three components (EF_C, EF_L, EF_M) of the total ecological footprint EF_{TOT} which is 58,367 gha, are summarised.

The difference between these two figures represents the EB, which generates a positive value of 3270 gha, establishing an environmental surplus and consequently a condition of (strong) sustainability of the local agricultural system.

4.4. Discussion

Analysing the results of the Viterbo case study, interesting insights emerge related to the composition of the BC_{TOT} and EF_{TOT} indicators and to the extent of their difference. As can be observed, the total biocapacity comes mainly from the crop land (about 78%); this data, which is unsurprising considering that the assessment referred to an agricultural system, can be analysed further by looking at the contribution of single crops to the total value. At the same time, the total ecological footprint of the Viterbo agricultural system comes from cultivation activities (64%) and, to a lesser extent, from livestock (31%). There are several reasons for this: the significant proportion of traditional cultivations (mainly cereals and olive trees), the widespread presence of extensive livestock (sheep and, in part, cattle), and also the fact that the impact of forage cultivation was included in the crops category, even if a considerable part of that production is intended for farmed animal feed.

In interpreting these data a limitation of the study, associated with the livestock GHG emissions calculation, has to be considered. Indeed, this impact was assessed applying national standard emission factors without

Table 3
Assessment of total CO_2 emissions from livestock in the municipality of Viterbo.

Type of animals	CH_4 emissions (kg/head year)	N_2O emissions (kg/head year)	CO_2-eq emissions (kg/head year)	Heads number	CO_2-eq emissions (tons/year)
Dairy cows	128.04	1.484	3148.9	2082	6556
Other cattle	52.82	0.430	1242.4	6267	7786
Buffalo	74.60	1.265	1958.9	272	533
Sheep	8.22	0.324	273.1	49,332	13,471
Goats	5.15	0.324	208.5	661	138
Horses	19.48	1.000	719.1	359	258
Other equines	10.84	1.000	537.6	35	19
Sows	21.10	0.028	451.8	858	388
Other pigs	8.29	0.013	178.0	12,329	2195
Laying hens	0.08	0.012	5.5	928,951	5084
Broilers	0.08	0.007	3.9	175,131	681
Other poultry	0.08	0.011	4.9	40,263	199
Rabbits	0.16	0.020	9.7	11,469	111
Total					37,418

Source: our elaboration of data extracted from ISTAT (2011), Coderoni and Bonati (2013).

taking into consideration local production techniques, as was done for the crop EF evaluation. To overcome this limit, municipality-specific emission factors related to local breeding techniques should be estimated (Baldoni et al., 2017).

The main result of this study is the value of the ecological balance, which in our case takes on a positive value, establishing a condition of sustainability of the local agricultural system. The small value of EB, which represents 5% of BC, suggests how easily this situation may be reversed. In this regard, all the information provided by the model can drive targeted local policies (of both an agricultural or environmental nature) to maintain, and possibly increase, the current value of ecological balance. For this reason, the EB values of single crops (listed in Table 2) represent very useful information, either to promote targeted modifications of some production techniques, or to support / discourage specific crops. Likewise, the farms with the greatest unsustainability can be identified and, consequently, this knowledge could drive the proper process aimed at reducing their environmental impact.

In terms of policy, an aspect that deserves attention is the role of organic farming in influencing the sustainability of the agricultural system. As regards cultivations, the effect of organic farming techniques on EB is generally ambiguous, considering: (i) the implications of different inputs typologies and quantities on EF_{inp}, and (ii) the possible effect of the expected yield reduction in decreasing both EF_{ovp} and BC. The impact on livestock management is more predictable, considering the organic farming constraints on the number of animals per unit area, resulting in a reduction of the EF caused by GHG emissions. However, even if a greater presence of organic farming might be expected to produce an EB improvement, the extent of this possible improvement is strictly site-specific and hence not easy to quantify.

Once the positive ecological balance condition has been maintained over a sufficient period, it will be possible to declare and, under the appropriate conditions, to certify the sustainability of the local agricultural system. Targeted and efficient communication of this special characteristic of the region, as discussed in the background section, can have positive implications for single actors in the local agro-food sector and, more generally, can lead to an effective sustainable development of the area.

5. Conclusions

The methodology proposed for the assessment of the sustainability of local agricultural systems, as shown by the case study, provides an effective synthetic indicator able to describe the balance between supply and demand for environmental services in a defined region. Despite the advantages of a relatively simple calculation of the ecological balance indicator and the clarity of its meaning, there is no doubt that the proposed approach can be subject to some criticisms.

A first element of discussion concerns the actual ability of the ecological footprint approach to describe and quantify the complex relationships between economic activities and the environment; in this regard, in presenting the methodology we have tried to argue how, despite some objective limitations, many authors agree in considering the ecological footprint as one of the most suitable indicators to obtain an operational assessment of sustainability.

A second aspect concerns the calculation method used to assess the supply of natural resources (biocapacity) for agricultural activities and the demand for those resources (ecological footprint) by agricultural activities within a given region. The assumptions underlying the methodology, some related to data availability and some to simplify the calculations, are certainly a matter for further discussion. From this point of view, there are significant opportunities for improving the model; for example refining the evaluation of the livestock environmental impact or adopting more reliable yield factors by considering the characteristics of the region analysed. These improvements on the analysis represent a crucial point for further extensions of the study.

Despite these limitations, it is reasonable to say that this tool can offer a useful contribution to drive local policies towards a more environmentally compatible agriculture and to communicate a brand of environmental sustainability. To this end, the calculation methodology could be applied to simulate the impact of different policy scenarios – such as the one linked to the targets posed by the recent EU Farm to Fork strategy - on cultivation and breeding activities and, consequently, on the sustainability of local agricultural systems.

Moving on to considerations about the effects of sustainability brands raised in the background section, we can state that when food products from a sustainable agricultural system reach consumers, the value of such products is likely to increase, thus improving both the economic performance and the environmental quality of the territory. For this to happen, the sustainability of the production system needs to be effectively verifiable and clearly communicated to consumers. In fact, the presence of both motivation and understanding in the consumer's mind determines their awareness of a sustainability brand, which is the necessary premise for environmental issues to be integrated into their food purchase choices.

Declaration of interests

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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