Dichiarazione sostitutiva di certificazione
(artt. 46 e 47 D.P.R.28 dicembre 2000 n. 445)

La sottoscritta Barbara Pancino nata a ROMA il 04/03/1977, residente a SUTRI in via dei Lucumoni 30, codice fiscale PNCBBR77C44H501X, consapevole che chiunque rilascia dichiarazioni mendaci è punito ai sensi del codice penale e delle leggi speciali in materia, ai sensi e per gli effetti degli artt. 46 e 47 D.P.R. n. 445/2000, relativamente al contributo dal titolo "The environmental sustainability of national cropping systems: from assessment to policy impact evaluation", di cui sono autori Nicolò Passeri, Emanuele Blasi, Silvio Franco, Barbara Pancino, Clara Cicatiello, pubblicato sulla rivista Land Use Policy, n.57 del 2016,

,

DICHIARA

- che il contributo è frutto di una riflessione comune degli autori;
- di aver redatto il paragrafo 5 "Conclusions";
- di aver letto e approvato con gli altri autori la versione finale del contributo.

Allega alla presente fotocopia della carta d'identità.

Viterbo, 14/11/2020

Firma

Barbara Pancino

Cognome .... PANCINO

Nome .... BARBARA

nato il 04-03-1977

(atto n. .... 703 P. .... 1 .... S. .... A ....)

a .... ROMA .... (........ RM ....)

Cittadinanza .... ITALIANA

Residenza .... SUTRI (VT)

Via .... VIA PRIMO MAGGIO,23

Stato civile .... ====

Professione .... ===

CONNOTATI E CONTRASSEGNI SALIENTI

Statura 1,80

Capelli .... CASTANI

Occhi .... CASTANI

Segni particolari .... NESSUNO

Firma del titolare. Barbara Pancino

SUTRI .... li 20-05-2016

d'ordine del Sindaco

IL SINDACO

Impronta del dito indice sinistro

SCADE IL 04-03-2027

Dir. C.I. E.5,00
Dir. Segreteria E.0,50

AX1887985

I.P.Z.S. S.p.A. - O.C.V. - ROMA

REPVBBLICA ITALIANA

COMVNE DI

SUTRI (VT)

CARTA D'IDENTITA'

N° AX1887985

DI

PANCINO

BARBARA

Land Use Policy 57 (2016) 305–312

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

The environmental sustainability of national cropping systems: From assessment to policy impact evaluation

N. Passeri[a,*], E. Blasi[b], S. Franco[c], A. Martella[a], B. Pancino[b], C. Cicatiello[c]

[a] *Agronomist Freelance—Viterbo, Italy*
[b] *Department for Innovation in Biological Agro Food and Forest system (DIBAF)—Università degli Studi della Tuscia, Italy*
[c] *Department of Economics and Management (DEIM)—Università degli Studi della Tuscia, Italy*

ARTICLE INFO

Article history:
Received 23 June 2014
Received in revised form 30 May 2016
Accepted 3 June 2016

Keywords:
Ecological footprint
Environmental impact
Cap policy
Crop system
Agro-environmental measures

ABSTRACT

The European political framework of the last decade aims to drive agriculture towards economic and environmental sustainability. Thus, European institutions have paid great attention to environmental impact assessment and to the definition of a complex indicator capable of restoring the multidimensional nature of environmental sustainability.

In this work, a possible methodology for assessing the environmental sustainability of European national cropping systems by a synthetic indicator is provided. More specifically, the environmental impact of agriculture is assessed through a synthetic indicator, whose definition is based on a methodological improvement of the ecological footprint approach, which quantifies the balance between exploitation and availability of natural resources used in agriculture.

The analysis shows how national cropping systems can contribute to Europe's environmental impact through agriculture. To assess an eventual relationship between agriculture's environmental performance and the ability to support more sustainable agriculture at the national level, the results are then compared with the subsidies for agro-environmental measures provided by the second pillar of the CAP. In addition, the synthetic indicator chosen for the study, giving the possibility of quantifying the dynamic of the environmental impact of agriculture between two different periods, permits the analysis of the possible causes that may have generated the observed changes.

The implications of this approach should stimulate new reflections on the significance of the ecological relationships embodied into agricultural production and the environmental role of farmers.

1. Introduction

Agriculture, food production safety and natural resource preservation are all closely linked. Therefore, researchers and institutions are constantly looking for tools and policies that can lead to solutions that help ensure economic efficiency, social equity and environmental sustainability. The latter is mainly focused on climate change mitigation and adaptation, biodiversity, and water and soil preservation. Indeed, public and private stakeholders seem to highlight the wide role of farming in the preservation of natural capital.

Since the 1980s, this role has been recognized by the Common Agricultural Policy (CAP), which started to activate measures for improving the sustainability of European agriculture. At the beginning, the aim of the CAP was maintaining farm income and acting on internal market prices, subsides to export, and taxes on commodities imported. Throughout the years, the same policies have imposed the so-called "production quotas" and "set-aside measures". While these charges stemmed from what was discussed in the Uruguay Round GATT (rules with respect to the support of domestic agriculture), the "new" reasons to fund agriculture were based on environmental issues (Grossman, 2003; Berger et al., 2006).

In the 1990s, the CAP was radically changed, with subsidies no longer linked to production but assigned with respect to cultivated areas and farming management practices. At the same time, with the 1992 and 1999 reforms, the CAP was enriched with the instruments of rural development, pursuing synergistic environmental action through the Agri-Environmental Schemes (AES). From 1992–2002, approximately 25% of agricultural land in the EU was under AES agreements (Freibauer et al., 2004; Primdahl et al., 2010).

* Corresponding author.
E-mail address: npasseri@unitus.it (N. Passeri).

http://dx.doi.org/10.1016/j.landusepol.2016.06.007
0264-8377/

Since their definition, AES were designed to ensure the protection, maintenance and enhancement of natural resources (water, soil, forests), biodiversity (species and habitat), and landscape. The AES payments are not directly related to the environmental performance but to the loss of income and/or the higher costs the farmer suffers as a result of the agri-environmental commitments that go beyond "good agricultural practice" (European Commission, 2005; Baylisa et al., 2008).

Since the Fischler CAP reform in 2003, the policy framework of environmental measures also included some mandatory constraints for farmers to fulfil in order to receive the direct payments provided by the CAP itself. The direct payments' cross-compliance, greening and AES are now integrated as tools that promote the sustainable management of natural resources by the primary sector. Although regulated by different policy mechanisms, the main objective of these tools is to increase the production of public goods, protection of the landscape, biodiversity conservation, adaptation and mitigation to climate change, availability and quality of water resources, and maintenance of soil fertility (European Commission).

This political framework aims to drive European agriculture towards economic and environmental sustainability (OECD, 2001; European Commission, 2006; OECD, 2008).

To define indicators able to test the effectiveness of the environmental measures still remains one of the Commission's main objectives, so the Commission-Eurostat, the Agriculture DG, the Environment DG, the Joint Research Centre and the European Environmental Agency (EEA) are all working on this topic. At the same time, researchers have proposed a wide range of indicators to assess the main environmental impact of the implementation of AES and the new greening payment tools.

Nevertheless, the voluntary environmental schemes proposed as part of the CAP and developed to answer to several and specific environmental issues, such as climate and sectorial structure (Keenleyside et al., 2011), are not standardized across European regions (Yli-Viikari et al., 2007). Thus, the CAP funds spent are not taken into account for their effectiveness as a result of a synergic action between economics and the environment but as a synthetic effort towards a general aim.

To link this gap, the strategic plan Europe 2020 integrates the concept of verifiability of environmental sustainability into the CAP policy (European Commission, 2006; Uthes and Matzdorf, 2013). Currently the European Commission proposes for AES evaluation a set of indicators to assess environmental topics both in the *ex-ante* (Common Context Indicators) and the *ex-post* (Target Indicators) analyses. This set, supported by national main statistics, will be used to evaluate each rural development plan.

Thus, the attention paid by European institutions to environmental impact assessment and the definition of a complex indicator capable of restoring the multidimensional nature of environmental sustainability (Gerdessen and Pascucci, 2013) is self-evident; such an indicator should give a clear picture of the environmental sustainability of agriculture in European countries and how it could be affected by sectorial policies (Collins and Fairchild, 2007).

This work, which is part of the above line of study, has a twofold purpose. The first is to present a possible methodology for assessing environmental sustainability, referring to the allocation among the different crops (crop mix) of the agricultural land in a country, of European "national cropping systems" with a synthetic indicator. The second objective is to use such a synthetic indicator to verify to what extent the CAP agri-environmental measures have increased the environmental performances of agriculture in different countries.

In the second section of the paper, the theoretical background of the so-called agriculture Ecological Balance indicator is described. This indicator, based on the general Ecological Footprint approach, seems to be able to assess the sustainability of agriculture by comparing its use/offer of natural resources. Indeed, farming activities, depending on bioclimatic zones and production techniques, can, at the same time, exploit and supply ecological services.

The third section presents the methodological approach adopted to evaluate the contribution of each European country cropping system to the environmental sustainability of European agriculture and to assess the possible effects of agri-environmental policies on the improvement of national cropping system sustainability. In this section, the datasets upon which the empirical analysis is based are also described, highlighting their characteristics and limits.

Finally, in the last section of the paper, the results obtained in the empirical analysis are presented and discussed.

The paper ends with some considerations about potentialities and limits of the proposed approach and possible suggestions for further research on this topic.

2. Assessing crops' environmental sustainability through the ecological footprint

The Ecological Footprint approach analyses the systemic interaction between the depletion and supply of natural resources. The depletion is measured through the ecological demand operated by humans and the supply through nature's ability to provide ecologic goods and services.

Introduced and developed by Rees and Wackernagel (1994) and Wackernagel and Rees (1996, 2008), the Ecological Footprint methodology provides a comparison between the natural capital consumption caused by human activities in a certain area and the ecological services that the natural ecosystems in the same area can provide.

More specifically, the Ecological Footprint indicator (EF) accounts for the demand of natural resource, while the Biocapacity indicator (BC) tracks the supply side and is evaluated considering the rate of resource regeneration and waste disposal that an area can sustain under the prevailing technology and management schemes. Both EF and BC are measured in a unit called global hectare (gha) that represents a standardized hectare with the world average productivity; it can also be thought of as a measure of the ecological productivity required to maintain a given product flow (Monfreda et al., 2004; Galli et al., 2007; Huijbregtsa et al., 2008).

The ecological footprint approach, because of its ability to assess an ecological balance between consumption and supply of natural resources, seems to be appropriate for evaluating the environmental sustainability of agriculture. Indeed, the definition of sustainable agriculture is concerned with the ability of agro-ecosystems to remain productive in the long-term and it implies the maintenance of the "natural capital" (the stock of ecological assets that provide a flow of useful goods or services) both as a "source" of inputs and as a "sink" for waste (Goodland, 1995).

Actually, in terms of sustainability, farming activities are mainly considered only from the point of view of their negative environmental impact (LCA analysis and greenhouse gasses emissions evaluation are two examples of such an approach). In this perspective, limiting the negative consequences of agricultural activities on ecosystems is the only effect of farmers' choices. In other words, farming activity is able to mitigate production impacts, ignoring its intrinsic capacity to provide ecosystem services.

The Ecological Footprint idea goes beyond this issue, taking into account resource exploitation due to farming choices (with the EF indicator) and the crop attitude into providing ecological services supply (with the BC indicator).

This possibility has induced many authors to adopt the Ecological Footprint methodology, improving and deepening specific

Table 1
Missing data in FAOSTAT databases and solution adopted.

Database		2002–04 Missing Data	2002–04 Used Data	2008–10 Missing Data	2008–10 Used Data
Pesticides	Herbicide, fungicides, insecticides	Bulgaria, Croatia, Luxembourg, Malta	Bulgaria: 1992 data; Croatia: 1996 data; Luxembourg: added to Belgium; Malta: average 1999–2000–2001 data	Bulgaria, Croatia, Greece; Luxembourg,	Bulgaria: 1992 data; Croatia: 1996 data; Greece: average 2005–2007 data; Luxembourg: added to Belgium;
Fertilizer	Nitrogen, phosphate, potash	Belgium; Ireland (source anomaly data)	Belgium: added to Luxembourg; Ireland: correction factor (x0.10)	Belgium; Ireland (source anomaly data)	Belgium: added to Luxembourg; Ireland: correction factor (x0.10)
Energy	Fuel	Cyprus; Germany; Malta	Cyprus: average 2005–2006–2007 data; Germany: average 1996–1997–1998; Malta: Missing data	Germany	Germany: average 1996–1997–1998
	Electricity	Slovenia	Slovenia: 2001 data	Slovenia	Slovenia: 2001 data

Source: our elaboration.

issues (Thomassen and De Boer, 2005; Liu et al., 2008; Limnios et al., 2009; Bagliani et al., 2008; Wiedmann et al., 2006). Namely, agricultural issues have been explored, paying attention to the effects of inputs, either for single cultivations (Tong et al., 2003) or at the global level (Ko et al., 1998); some quantitative analyses based on case studies have also been provided (Deumling et al., 2003; Van der Werf et al., 2006; Cuandra and Bjorklund, 2007).

Despite these efforts, some methodological aspects have limited the possibility to analyse agriculture's environmental impacts through the EF approach. Namely, some authors have highlighted how the original EF methodology provides a similar way to evaluate the EF and BC indicators for agricultural land (Mózner et al., 2012). This feature is not suitable for a correct sustainability assessment (Fiala, 2008) and avoids a helpful measure for designing agricultural environmental policies (Ferng, 2005).

Recently, a methodological upgrade has been proposed to overcome these limitations and to afford a more consistent method of evaluation of the agricultural ecological footprint. This methodological improvement, so-called “FarSo” (Passeri et al., 2013), maintains the fundamental relationship between EF and BC indicators, providing at the same time a new calculation technique of crops' ecological footprint; more specifically, every cultivation technique has a specific impact that can be evaluated and compared with the biocapacity produced by the crop itself.

The crop's EF is calculated as the sum of two components: the first is due to the impact associated with the inputs required to manage the crop cultivation (EF_{inp}); the second is linked to the exploitation of land productivity measured as the overproduction with respect to the “minimum” input productivity (EF_{ovp}). The EF_{inp} can be evaluated by choosing the more feasible values according to the GFN database used in the National Footprint Account (GFN, 2011) and using published research and international references, as reported in Passeri et al. (2013). The EF_{ovp} must refer to a baseline level of production, namely the quantity produced by the natural system with the “lowest” level of external inputs (“minimum input production”), so the overproduction can be defined as the production over the natural minimum.

This approach builds a framework and organizes the information needed for a more complete evaluation of the farming activity; more specifically, the results, on one side, take into account the impacts (EF) determined by the farmer's choices in terms of inputs and management and, on the other side, the biocapacity (BC) originated by the amount of bioproductivity that the crop shows as a reaction to the management activity.

The difference between BC and EF can be interpreted as an Ecological Balance (EB) indicator. If EB is positive, the cultivation activity has generated an ecological services surplus, the extent of which is measured in the number of global hectares made available, for example, for other crops. In contrast, if EB is negative, the crop is not sustainable because it needs more natural resources than what is provided by the land on which it is cultivated.

To clarify these concepts and to show how the EF, BC and EB are calculated, an example will be provided in the methodological section.

3. Materials and methods

3.1. Methodological approach

The cropping system environmental performances at the country level have been analysed using an approach based on the “FarSo” methodology, as presented in the previous section.

For each one of the n = 28 EU countries, the ecological balance (EB_i) is calculated as the difference between the overall biocapacity (BC_i) and the ecological footprint (EF_i) of national cropping systems:

$$EB_i = BC_i - EF_i$$

The overall biocapacity of a national cropping system is obtained as the sum of the biocapacity provided by each one of the m crops:

$$BC_i = \sum_{j=1}^{m} \left(\frac{P_{ij}}{Yw_j} \cdot A_{ij} \right) \cdot EQF$$

where P_{ij} = average productivity of crop j in country i (tons/ha), Yw_j = world productivity of crop j (tons/ha), A_{ij} = cultivated area of crop j in country i (ha), EQF = equivalence factor (gha/ha), *i.e.* the scaling factor used to convert a specific land-use (ha) into global hectares (gha); in other words, it is the characterisation factor useful for aggregating different types of land use in terms of “*bioproductive area*” (Huijbregtsa et al., 2008).

The EF of each country's crop system is calculated taking into account the two components, inputs (EF_{inp}) and overproduction (EF_{ovp}), according to the FarSo model (Passeri et al., 2013):

$$EF_i = EF_{inp_i} + EF_{ovp_i} = \sum_{k=1}^{p} (Q_{ki} \cdot F_k) + \sum_{j=1}^{m} \left(\alpha_{ij} \frac{P_{ij}}{Yw_j} \cdot A_{ij} \right) \cdot EQF$$

where p = number of inputs considered, Q_{ki} = quantity of input k used in country i (for the units of each input see paragraph 3.2), F_k = conversion factor of input k to EF; such factor considers the embodied footprint in the input expressed as CO_2 emissions and converts it in terms of gha (Passeri et al., 2013), α_{ij} = overproduction factor calculated as:

$$\alpha_{ij} = \frac{P_{ij} - P'_{ij}}{P_{ij}}$$

with P'_{ij} indicating "minimum input production" of crop j in country i. By "minimum input production" we mean a baseline level of production, namely the quantity produced by the natural system with the "lowest" level of external inputs. This value is not easy to determine, and it has to be selected case by case considering the specific conditions.

Once the EB_i is calculated, it is possible to evaluate a so-called "sustainability index" (SI) as the ratio between EB and the Utilized Agricultural Area (UAA) for each country. This index expresses the environmental performance of each national cropping system in relative terms because it measures the extent of ecological services deficit/surplus (measured in gha) originated by one hectare of agricultural land.

An example can be useful to explain and clarify the methodology. Let us consider an area of 30 ha that has been cultivated with durum wheat with a yield of P = 2.20 tons/ha. The crop's EF_{inpi} is due to the inputs used – fertilizers, pesticides and fuel for machinery operations – in the cultivation process and is calculated converting in terms of gha the quantities of the p inputs (Q_k) by means of the appropriate conversion factors (F_k), as specified in Passeri et al. (2013), obtaining a value of EF_{inpi} = 37.84 gha. To calculate EF_{ovpi}, the durum wheat yield (P') under a minimum input cultivation should be known. In this example, this information could be deduced through a specific investigation on a well-established experimental plan, with the aim of detecting the crop productivity under "natural conditions" in a comparable agro-ecosystem. Assuming that such a value is P' = 1.43 ton/ha, the overproduction factor is $\alpha = 0.35$. Thus, considering that for durum wheat the world yield is Yw = 2.35 tons/ha and that EQF = 2.51 gha/ha, it results in EF_{ovpi} = 24.67 gha. Adding the two components, we obtain EF = 62.51 gha. Using the same coefficients (Yw and EQF), BC is calculated as $(2.20/2.35) \times 30 \times 2.51 = 70.49$ gha. Thus, the Ecological Balance is EB = 70.49 − 62.51 = 7.98 and SI = 7.98/30 = 0.266. In this example, the durum wheat cultivation impact (EF) is sustained by the biocapacity of the crop itself (BC), so there is an environmental surplus.

Coherently with the second objective set in the introduction, the changes in national cropping systems' sustainability, measured as the SI variation, may be analysed as a potential outcome of European agri-environmental policies. To capture such a possible cause-effect relationship at the national level, a simple linear regression model has been utilized:

$$Y = a + b \cdot X$$

placing agri-environmental payments as the independent variable (X) and the SI variation as the dependent one (Y).

3.2. Characteristics of the dataset

The crops' production and input dataset of the 28 European Union countries has been collected from the FAOSTAT database. Data on crop cultivation (harvested area, production quantity, yield) were collected from 1995 to 2010. Data on 117 crops were retrieved from the database, including all of the annual crops (cereals, vegetables, industrial crops, *etc.*), fruit trees and other fruits, while grassland and pastures have been excluded.

With reference to agricultural inputs, the following national data have been extracted from the database referring to the time range 2002–2010: fertilizers (nitrogen, phosphate, potassium; all measured in tons); pesticides (fungicides, herbicides, insecticides; all measured in tons); energy (fuels; measured in terajoule); and electricity (measured in million kWh).

Table 2
Agri-environmental payments in EU-15 countries.

Country	Payments 2003-09 *[€/ha]*
Austria	122.31
Belgium-Luxembourg	108.00
Denmark	95.21
Finland	93.83
France	33.19
Germany	88.84
Greece	332.36
Ireland	124.17
Italy	180.88
Netherlands	235.59
Portugal	142.25
Spain	228.75
Sweden	88.42
UK	89.18

Source: our elaboration on DG AGRI (2014) data.

The analysis has taken into account two different 3-year periods: 2002–04 and 2008–10. The so organized dataset has shown some gaps related to the availability of input data. Table 1 explains the missing data and how this lack of information has been filled for the analysis.

The reference data required to calculate BC and EF, in particular the crops world productivity (Ywj), were gathered from the GFN database used in the National Footprint Account (GFN, 2011).

With reference to agri-environmental payments (Reg. EEC no.2078/1992; Council Reg. EC no.1257/1999; Reg. EC no. 1698/2005), data for the EU-15 countries from 2003 to 2009 were collected from the DG AGRI database. These values were added and then divided for the total utilized agricultural area, obtaining a cumulative payment per hectare over the whole period (Table 2).

3.3. Data analysis

In accordance with the methodology described in the previous section, the biocapacity of national cropping systems (BC) has been evaluated considering the weighted average of the crop production for each of the two 3-year periods analysed (2002–2004 and 2008–2010).

The EF originated by the inputs utilized in crop cultivation (EF_{inp}) has been calculated as a 3-year average for the two considered periods.

To calculate the EF_{ovp}, the minimum input production (yield) for each crop is needed. As noted in the methodology description, this is a particularly difficult task, as this value should be known for all of the crops in each of the investigated countries. In the absence of such information, it was decided to roughly estimate this figure as the tenth percentile of the yield data derived from the 1995–2010 historic series for each crop in each country. With this choice, we assume that the minimum input yield can be approximated with the yield occurring in low productivity conditions. The α_{ij} coefficients and the EF_{ovp} in both periods have been thus evaluated.

Then, subtracting EF (EF_{inp}+ EF_{ovp}) from BC, the national ecological balances (EB) have been obtained.

4. Results and discussion

Table 3 shows the results of such evaluation for the period 2008–2010. The last column reports a "sustainability index" (SI), which expresses the ecological services deficit/surplus associated with one hectare of agricultural land in each country.

For Europe, the results show a low ecological deficit in terms of total gha and, hence, a very small level of unsustainability. Never-

Table 3
Environmental analysis at European Level, 2008–2010 results.

	BC *[mil gha]*	EFinp *[mil gha]*	EFovp *[mil gha]*	EB *[mil gha]*	UAA *[mil ha]*	SI *[mil ha]*
Austria	6.79	3.67	1.39	1.73	1.15	1.51
Belgium-Luxembourg	4.77	7.41	0.73	−3.37	0.63	−5.31
Bulgaria	11.21	4.73	4.13	2.36	2.94	0.80
Croatia	3.55	4.57	0.74	−1.76	0.81	−2.17
Cyprus	0.17	0.34	0.07	−0.24	0.08	−3.14
Czech Republic	11.21	6.78	1.87	2.57	2.18	1.18
Denmark	12.31	8.80	1.38	2.12	1.77	1.20
Estonia	1.22	1.12	0.35	−0.24	0.41	−0.59
Finland	5.25	8.87	1.08	−4.70	1.26	−3.74
France	92.80	61.70	11.55	19.55	13.96	1.40
Germany	67.55	54.73	6.76	6.06	9.37	0.65
Greece	10.85	8.90	1.15	0.79	2.68	0.30
Hungary	17.07	7.45	4.15	5.47	3.95	1.38
Ireland	2.84	2.78	0.38	−0.31	0.33	−0.93
Italy	32.04	32.06	4.63	−4.65	7.39	−0.63
Latvia	2.36	1.82	0.55	−0.02	0.68	−0.02
Lithuania	4.84	1.53	1.74	1.57	1.39	1.13
Malta	0.04	0.01	0.01	0.02	0.01	1.62
Netherlands	4.46	27.40	0.58	−23.53	0.57	−41.09
Poland	39.53	53.31	7.85	−21.63	10.68	−2.03
Portugal	2.70	4.80	0.69	−2.79	1.28	−2.19
Romania	20.48	6.28	8.36	5.84	7.44	0.79
Slovakia	4.61	2.05	1.24	1.32	1.12	1.19
Slovenia	0.63	1.11	0.12	−0.60	0.14	−4.21
Spain	42.54	29.53	16.56	−3.54	12.61	−0.28
Sweden	6.74	4.55	0.81	1.39	1.24	1.12
United Kingdom	33.40	16.46	3.40	13.54	4.36	3.10
EU-28	**441.95**	**362.71**	**82.28**	**−3.03**	**90.43**	**−0.03**

Source: our elaboration.

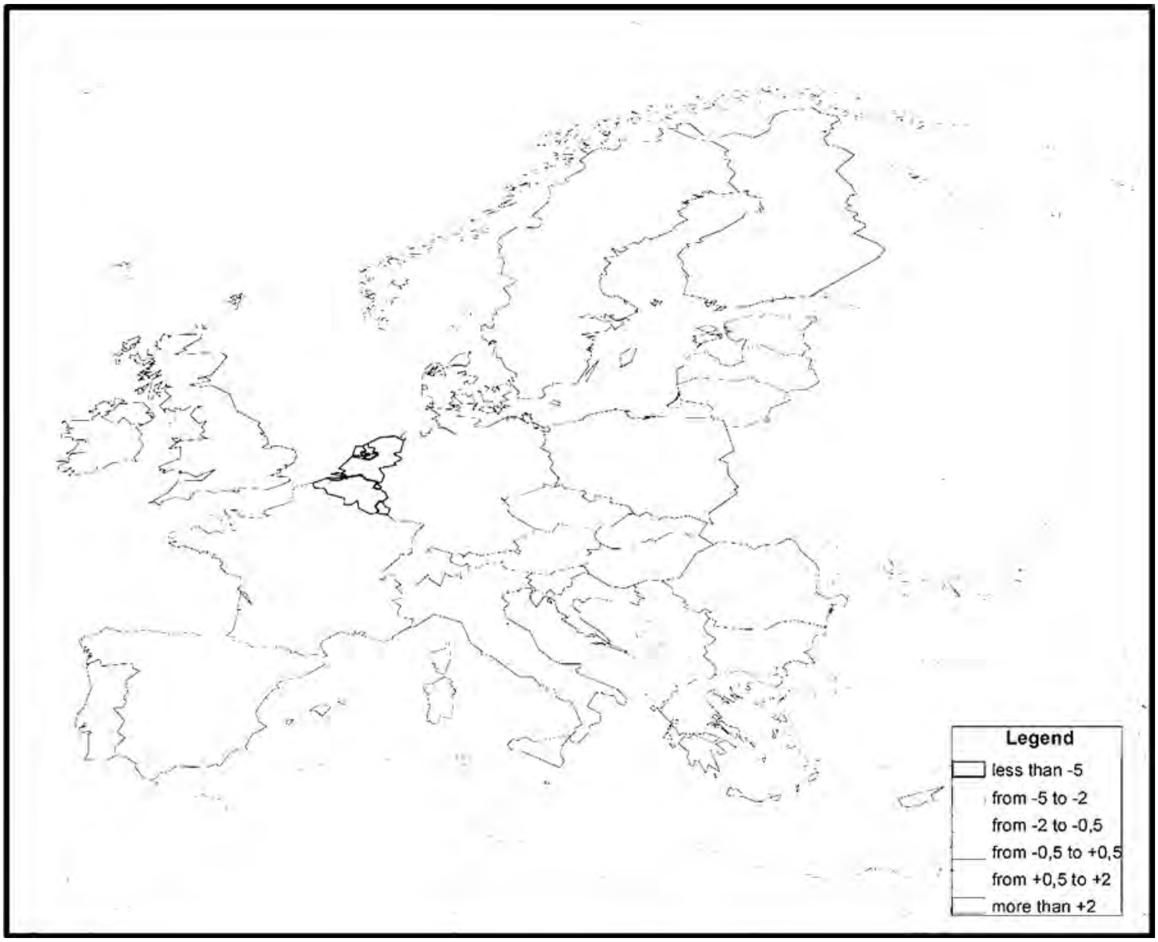

Fig. 1. Ecological performance of European cropping systems in gha/ha (2008–2010).

theless, the individual countries' contributions to this result change throughout Europe. The nations with fully sustainable cropping systems are coloured in shades of green in Fig. 1, while those with unsustainable cropping systems are in red. The nations coloured yellow show a substantial balance between BC and EF.

The belt of northern-central European cropping systems, with the exclusion of Poland, shows a diffuse ecological surplus; these countries are the highest EF producers in Europe because of utilized agricultural areas. At the same time, however, their cropping systems are able to generate a high ecological supply that overcompensates the demand of natural resources.

Throughout the Mediterranean region, countries are generally close to the ecological draw. Actually, Spain and Italy show a low deficit, while Greece appears to have a small margin of ecological surplus. Italy and Spain show a different situation with respect to the two components of EF; indeed, the ecological footprint of the Italian cropping system is mainly due to the high use of input (EF_{inp}), while in Spain, the weight of the EF_{ovp} component largely prevails. This latter figure could be linked to the widespread presence of some crops (such as cereals and olive trees) that some areas, not fully suitable for such crops, are "forced" to reach high production levels resulting in an overexploitation of soil productivity.

Some new-entry countries show signs of unsustainability, such as Poland, Croatia and Slovenia, Finland, Portugal and, with a very high level of unsustainability, the Benelux area: here, the figure describing the overexploitation of natural resources caused by the agricultural systems erodes all of the ecological supply made available from French and German cropping systems. Even if the data source does not permit a detailed analysis, this result can be explained by the large use of inputs (pesticides, fertilizers and energy) linked to the large diffusion of greenhouses and reasonably also attributable to the cultivation of non-food crops (*e.g.*, flowers).

The only "deep green" country appears to be the United Kingdom, where the cropping systems have a limited ecological footprint and, at the same time, a good level of biocapacity. This exceptional combination originates a surplus of environmental services assessed in more than 3 gha for each cultivated hectare.

To test the trend of ecological performances of European cropping systems, the results of the previous analysis were compared with the national ecological balance for the period 2002–2004 calculated with the same methodology. The outcomes of this analysis are summarized in Table 4 and graphically represented in the map of Fig. 2.

The data show the definite and quite generalized improvement of European countries' cropping system performances across these two periods. The improvement reflects all countries except Croatia, Malta and, for a minimum account, Finland, Lithuania and Romania.

The northern-central European countries (Sweden, Germany, the UK, Ireland, Austria) contribute with a high improvement in their environmental cropping system performances that can be quantified in about one gha per ha of ecological surplus during the considered period. All Mediterranean countries (Spain, Portugal, Italy, Greece and France) have also obtained an improvement in environmental performances, even if a bit lower.

This positive trend can be explained by a more efficient use of inputs linked to the optimization of farming techniques and with a general decrease in cultivations in the less suitable areas where the scarce productivity of land brings low yields even in the presence of a high input management.

Evaluating the outcomes of both analyses (the static refers to 2008-10, and the dynamic is based on the comparison between 2002 and 2004 and 2008–2010), it must be considered that the utilized data suffer from several approximations due to the lack and reliability of information collected in the FAOSTAT database. Therefore, even if the trends seem to be quite clear, the individual values may be significantly under- or overestimated.

Table 4
Environmental analysis at the European Level, 2008–2010 and 2002–2004 results.

	SI (2008–10)	SI (2002–04)	ΔSI
Austria	1.51	−0.50	2.00
Belgium-Luxembourg	−5.31	−5.47	0.15
Bulgaria	0.80	−0.19	0.99
Croatia	−2.17	−1.47	−0.70
Cyprus	−3.14	−3.97	0.83
Czech Republic	1.18	0.82	0.36
Denmark	1.20	0.82	0.38
Estonia	−0.59	−1.54	0.94
Finland	−3.74	−3.71	−0.04
France	1.40	1.03	0.37
Germany	0.65	−0.20	0.85
Greece	0.30	−0.67	0.97
Hungary	1.38	0.69	0.69
Ireland	−0.93	−2.12	1.19
Italy	−0.63	−1.15	0.52
Latvia	−0.02	−0.85	0.82
Lithuania	1.13	1.14	0.00
Malta	1.62	1.83	−0.21
Netherlands	−41.09	−51.74	10.65
Poland	−2.03	−2.48	0.45
Portugal	−2.19	−2.53	0.34
Romania	0.79	0.88	−0.09
Slovakia	1.19	1.04	0.15
Slovenia	−4.21	−4.89	0.68
Spain	−0.28	−0.76	0.48
Sweden	1.12	0.14	0.97
United Kingdom	3.10	2.39	0.72
EU-28	**−0.03**	**−0.63**	**0.60**

Source: our elaboration.

The variation of national cropping systems' sustainability has been considered to develop an explorative analysis on the possible effect of the agri-environmental payments provided by CAP. The objective is to reach a first suggestion of the agricultural policies effectiveness in terms of re-orientation of national productive systems towards higher levels of sustainability.

For this purpose, agri-environmental payments per hectare cumulated over the period 2003–2009 have been compared with the variation of the sustainability index as calculated before (Table 5).

The possible cause-effect relationship between these two variables, as mentioned in the methodology, has been investigated through a simple linear regression model.

The results of the regression model show a positive effect of higher payments on the sustainability level with the *b* coefficient having a value of 0.013 gha/€; this indicates that, on average, a payment of 100 euros/ha has generated a sustainability improvement of 1.3 gha/ha. Even if this coefficient is barely significant ($p < 0.1$ for the one-tail *t*-test), the outcome can be considered interesting in a wider perspective for its ability to establish a quantitative assessment of the policy's impact on sustainability. Showing no significance at all is the a coefficient (in our case, equal to −0.379), which should represent the variation of the sustainability index in the absence of agri-environmental subsidies.

The low r-square value (0.135) and the absence of a significant predictive power of the model confirm the substantial unreliability of the results, which should be read only in a general perspective. Moreover, it must be considered that the sustainability index has been calculated through an approach that requires for further validation and using an unreliable dataset.

These considerations lead to the conclusion that, beyond its current limitations, the proposed approach could represent a useful tool for assessing and monitoring agricultural system sustainability at the country level. On the other hand, the idea of a direct (and measurable) influence of agricultural policies on crop system sustainability should be considered very carefully. The investigation of this cause-effect relationship, as indicated by our results, requires a

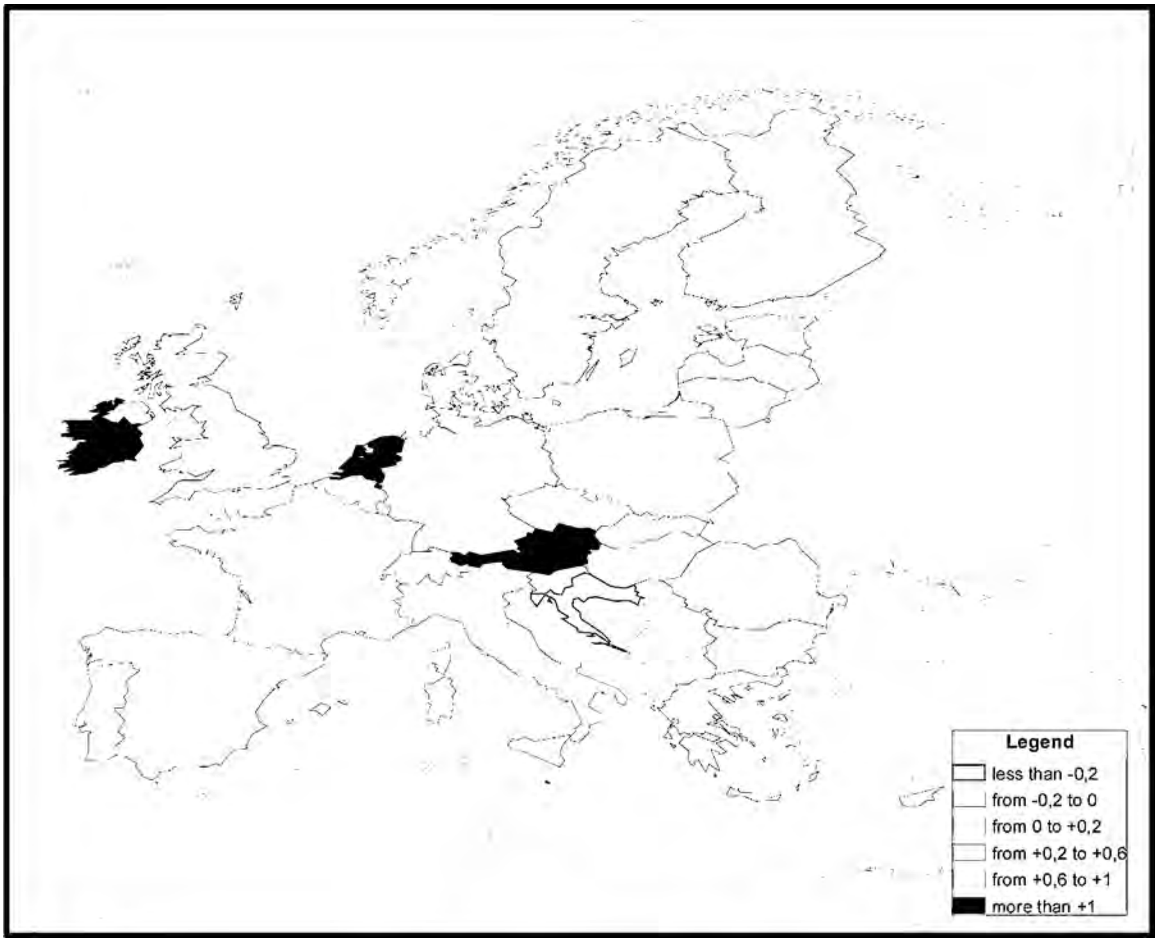

Fig. 2. Ecological Balance variation for cropping systems at the European level [gha/ha].

Table 5
Agri-environmental payments and variation of sustainability in EU-15 countries.

	Agri-environmental payments 2003–09 *[€/ha]*	SI variation 2002–04/2008–10 *[gha/ha]*
Austria	122.31	2.00
Belgium-Luxembourg	108.00	0.15
Denmark	95.21	0.38
Finland	93.83	−0.04
France	33.19	0.37
Germany	88.84	0.85
Greece	332.36	0.97
Ireland	124.17	1.19
Italy	180.88	0.52
Netherlands	235.59	10.65
Portugal	142.25	0.34
Spain	228.75	0.48
Sweden	88.42	0.97
UK	89.18	0.72

Source: our elaboration on DG AGRI (2014) data.

larger number of observations based on reliable data and, probably, a more in-depth statistical approach.

5. Conclusions

The aim of this paper was to propose an assessment of the environmental impacts of European countries' cropping systems and to compare the variation of such impacts with the subsidies provided by agri-environmental policies. This topic appears in line with the efforts made in the last decade to encourage more respectful environmental behaviour among farmers and, at the same time, highlights the difficulties of evaluating the real effectiveness of the policies that have accompanied this effort.

In the current paper, the environmental impact of agriculture has been measured through a synthetic indicator that quantifies the balance between exploitation and availability of natural resources needed for agricultural activities. This "sustainability indicator", whose definition is based on a methodological improvement of the ecological footprint approach, is able to express the environmental impact of national cropping systems. Furthermore, it allows for the analysis of the drivers of the observed changes in the environmental impact of agriculture along two different periods. Here the variations of the sustainability index of European countries' cropping systems have also been associated with the amount of environmental subsidies.

The results show a substantial balance between the demand for natural resources and the environmental services supply in Europe on a country level; this condition has been achieved because of the generalized improvement of the European cropping system sustainability, although some countries emerge as providers of natural resources (*i.e*., their national cropping systems are sustainable), while others are net consumers (*i.e*., they have a deficit in ecological balance).

Under a policy perspective, it would be very useful to read these results as a possible effect of the interventions aimed at reducing the environmental impact of agriculture. The regression analysis conducted for this purpose has provided interesting, but not definitive, clues. The connection that emerges between the amount of agro-environmental payments and sustainability improvement, although quite clear, is not significant and it does not allow for drawing reliable conclusions.

Some intrinsic limitations should, however, be taken into account when evaluating the results of the study. First, the ecological footprint approach itself is still far from being shared as a method for a consistent evaluation of environmental sustainability. Second, the dataset does not appear complete and fully reliable; namely, it should be improved for a deeper investigation of the cause-effect relationships between subsidies and environmental impact reduction.

Despite the need for theoretical insights and more suitable data, this study proposes a useful contribution to the discussion about the assessment of environmental performances of agriculture. European agricultural policies can take advantage of tools that include the analysis of the environmental supply production's attitude of farms besides their resources consumption/savings. This approach can lead to allocating the economic subsidies in a more environmentally oriented way, thus contributing to the reduction of the negative environmental impacts of agricultural activities.

The implications of this approach should then stimulate new reflections on the significance of the ecological relationships embodied in agricultural production and the environmental role of farmers.

References

Bagliani, M., Galli, A., Niccolucci, V., Marchettini, N., 2008. Ecological footprint analysis applied to a sub-national area. The case of the province of Siena (Italy). J. Environ. Manag., 354–364.

Baylisa, K., Peplow, S., Rausser, G., Simon, L., 2008. Agri-environmental policies in the EU and United States: a comparison. Ecol. Econ., 753–764.

Berger, G., Kaechele, H., Pfeffer, H., 2006. The greening of the European common agricultural policy by linking the European-wide obligation of set-aside with voluntary agri-environmental measures on a regional scale. Environ. Sci. Policy, 509–524.

Collins, A., Fairchild, R., 2007. Sustainable food consumption at a sub-national level: an ecological footprint, nutritional and economic analysis. J. Environ. Policy Plan. 9 (1), 5–30.

Cuandra, M., Bjorklund, J., 2007. Assessment of economic and ecological carrying capacity of agricultural crops in Nicaragua. Ecol. Indic. 7 (1), 133–149.

Deumling, D., Wackernagel, M., Monfreda, C., 2003. Eating up the Earth: How Sustainable Food Systems Shrink Our Ecological Footprint Redefining Progress, Available at http://www.rprogress.org/newpubs/2003/ag_food_0703.pdf (Last access February, 2008).

European Commission, 2005, Agri-Environment Measures Overview on General Principles, Types of Measures and Application. European Commission, Brussels, DG Agriculture.

European Commission, 2006, Development of agri-environmental indicators for monitoring the integration of environmental concerns into the common agricultural policy, Communication from the commission To the council and the european parliament, Brussels COM (2006) 508 final.

Ferng, J., 2005. Local sustainable yield and embodied resources in ecological footprint analysis-a case study on the required paddy field in Taiwan. Ecol. Econ., 415–430.

Fiala, N., 2008. Measuring sustainability: why the ecological footprint is bad economics and bad environmental science. Ecol. Econ. 67, 519–525.

Freibauer, A., Rounsevell, M.D.A., Smith, P., Verhagen, J., 2004. Carbon sequestration in the agricultural soils of Europe. Geoderma, 1–23.

Galli, A., Kitzes, J., Wermer, P., Wackernagel, M., Niccolucci, V., Tiezzi, E., 2007. An exploration of the mathematics behind the ecological footprint. Int. J. Ecodyn., 250–257.

Gerdessen, J.C., Pascucci, S., 2013. Data envelopment analysis of sustainability indicators of European agricultural systems at regional level. Agric. Syst., 78–90.

GFN—Global Footprint Network, 2011, National Footprint Account, Global Footprint Network.

Goodland, R., 1995. The concept of environmental sustainability. Annu. Rev. Ecol. Syst., 1–24.

Grossman, M.R., 2003. The uruguay round agreement on agriculture and domestic support. In: Cardwell, M.N., Grossmann, M.R., Rodgers, C.P. (Eds.), Agriculture and International Trade Law, Policy and the WTO. CABI Publishing, Wallingford, pp. 27–48.

Huijbregtsa, M.A.J., Hellweg, S., Frischknecht, R., Hungerbühler, K., Hendriks, A.J., 2008. Ecological footprint accounting in the life cycle assessment of products. Ecol. Econ. 64 (4), 798–807.

Keenleyside, C., Allen, B., Hart, K., Menadue, H., Stefanova, V., Prazan, J., Herzon, I., Clement, T., Povellato, A., Maciejczak, M., Boatman, N., 2011, Delivering environmental benefits through entry level agri-environment schemes in the EU. Report Prepared for DG Environment, Project ENV.B.1/ETU/2010/0035. Institute for European Environmental Policy, London.

Ko, Y.Y., Hall, C.A.S., Loípez Lemus, L.G., 1998. Resource use rates and efficiency indicators of regional sustainability: an examination of five countries. Environ. Monit. Assess., 571–593.

Limnios, E.A.M., Ghadouani, A., Schilizzi, S., Mazzarol, T., 2009. Giving the consumer the choice: a methodology for product ecological footprint calculation. Ecol. Econ., 2525–2534.

Liu, Q.P., Lin, Z.S., Feng, N.H., Liu, Y.M., 2008. A modified model of ecological footprint accounting and its application to cropland in Jiangsu, China. Pedosphere 18 (2), 154–162.

Mózner, Z., Tabi, A., Csutora, M., 2012. In the quest for the sustainable agricultural yield—comparing the environmental impacts of intensive and extensive agricultural practices. Ecol. Indic. 16, 58–66.

Monfreda, C., Wackernagel, M., Deumling, D., 2004. Establishing national natural capital accounts based on detailed Ecological Footprint and biological capacity assessments. Land Use Policy, 231–246.

OECD, 2008, Environmental performance of agriculture in Oecd countries since 1990, Paris, France.

OECD, 2001, Environmental Indicators for Agriculture: Methods and Results, vol. 3, Paris, France.

Passeri, N., Borucke, M., Blasi, E., Franco, S., Lazarus, E., 2013. The influence of farming technique on cropland: a new approach for the Ecological Footprint. Ecol. Indic., 1–5.

Primdahl, J., Vesterager, J.P., Finn, J.A., Vlahos, G., Kristensen, L., Vejre, H., 2010. Current use of impact models for agri-environment schemes and potential for improvements of policy design and assessment. J. Environ. Manag., 1245–1254.

Rees, W.E., Wackernagel, M., 1994. Ecological footprints and appropriated carrying capacity: measuring the natural capital requirements of the human economy. In: Jansson, A., Hammer, M., Folke, C., Costanza, R. (Eds.), Investing in Natural Capital: the Ecological Economics Approach to Sustainability. Island Press, Washington, pp. 362–390.

Thomassen, M.A., De Boer, I.J.M., 2005. Evaluation of indicators to assess the environmental impact of diary production systems. Agric. Ecosyst. Environ., 185–199.

Tong, C., Hall, C.A.S., Wang, H., 2003. Land use change in rice, wheat and maize production in China (1961–1998). Agric. Ecosyst. Environ., 523–536.

Uthes, S., Matzdorf, B., 2013. Studies on agri-environmental measures: a survey of the literature. Environ. Manag., 251–266.

Van der Werf, H.M.G., Tzilivakis, J., Lewis, K., Basset-Mens, C., 2006. Environmental impacts of farm scenarios according to five assessment methods. Agric. Ecosyst. Environ. 118 (1–4), 327–338.

Wackernagel, M., Rees, W.E., 1996, L'Impronta Ecologica. Come ridurre l'impatto dell'uomo sulla terra, Edizioni Ambiente, Milano.

Wackernagel, M., Rees, W., 2008, L'impronta ecologica, come ridurre l'impatto dell'uomo sulla terra, Edizioni Ambiente, Roma.

Wiedmann, T., Minx, J., Barrett, J., Wackernagel, M., 2006. Allocating ecological footprints to final consumption categories with input–output analysis. Ecol. Econ. 56, 28–48.

Yli-Viikari, A., Hietala-Koivu, R., Huusela-Veistola, E., Hyvo ̈nen, T., Perala, P., Turtola, E., 2007. Evaluating agri-environmental indicators (AEIs)—use and limitations of international indicators at national level. Ecol. Indic., 150–163.