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

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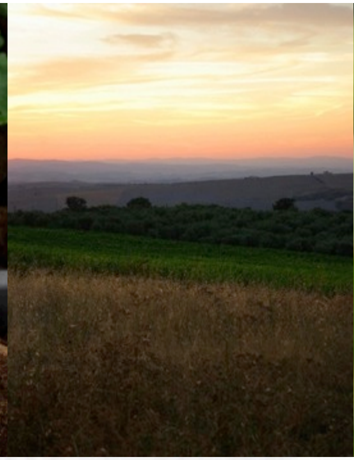
1. Purpose of analysis

To define indicators able to test the effectiveness of the environmental measures still remains one of the main Commission's objectives.



The aim of this work is to present a synthetic indicator to assess the environmental sustainability of European national cropping systems and to verify if the CAP agri-environmental measures have increased the environmental performances of agriculture in different countries.

2. Background

- The Ecological Footprint approach analyses the systemic interaction between depletion and supply of natural resources Rees and Wackernagel (1994, 1996, 2008)

- It provides a comparison between the natural capital consumption caused by human activities (Ecological Footprint - EF) in a certain area and the ecological services that the natural ecosystems in the same area can provide (Biocapacity – BC); both indexes are expressed into functional units called global hectars (gha)

- An ecological balance (EB) between consumption and supply of natural resources can be assessed

- The ecological footprint approach has been recommended as common methods to measure and communicate environmental performances by EU Commission (2013/179/UE)

2. Background

- Indeed, into methodology's main equation, EF and BC are both based on the same flow accounting calculation (Mozner, 2012): there is no possibility of any overexploitation of natural resources for crops production, because the equation for EF and BC is the same

- This limitation has been raised by some authors, whom have argued that such an evaluation of EF and BC is not suitable for a correct sustainability assessment (Fiala, 2008; Ferng, 2005)

- A new variation overcomes the main methodology. This is called "FarSo" (Passeri et al., 2013), maintains the fundamental relationship between EF and BC indicators, but providing a new calculation technique of crops' ecological footprint


3. Methodological approach

- To analyse the cropping system environmental performances at country level an approach based on the "FarSo" methodology has been adopted.

- 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:

$$EB_i = BC_i - EF_i$$

4. An assessment of EU countries' cropping system sustainability

The Ecological Footprint of each country crop system is calculated taking into account the two components, inputs (EF_{inp}) and overproduction (EF_{ovp}), according with the FarSo model:

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

where

p = number of inputs considered;

Q_{ki} = quantity of input k used in country i;

F_k = conversion factor to EF;

a_{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.

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

where:

P_{ij} = average productivity of crop j in country i;

Yw_j = world productivity of crop j;

EQF = equivalence factor;

A_{ij} = cultivated area of crop j in country i.

4. An assessment of EU countries' cropping system sustainability

The data set on crops' production and inputs utilized for each one of the 28 European Union countries has been collected from the FAOSTAT database, managed by FAO.

- Data on crops cultivation (harvested area, production quantity, yield) have been collected from 1995 to 2010.
- With reference to the agricultural inputs, national data on utilized fertilizers (nitrogen, phosphate, potash), pesticides (fungicides, herbicides, insecticides) and energy (fuels, electricity) from 2002 to 2010 have been extracted from the database.
- The analysis has taken into account two different periods of three years each: 2002-04 and 2008-10
- Impacts conversion factor (used into EF_{inp}) of for each of inputs come from published research and international references

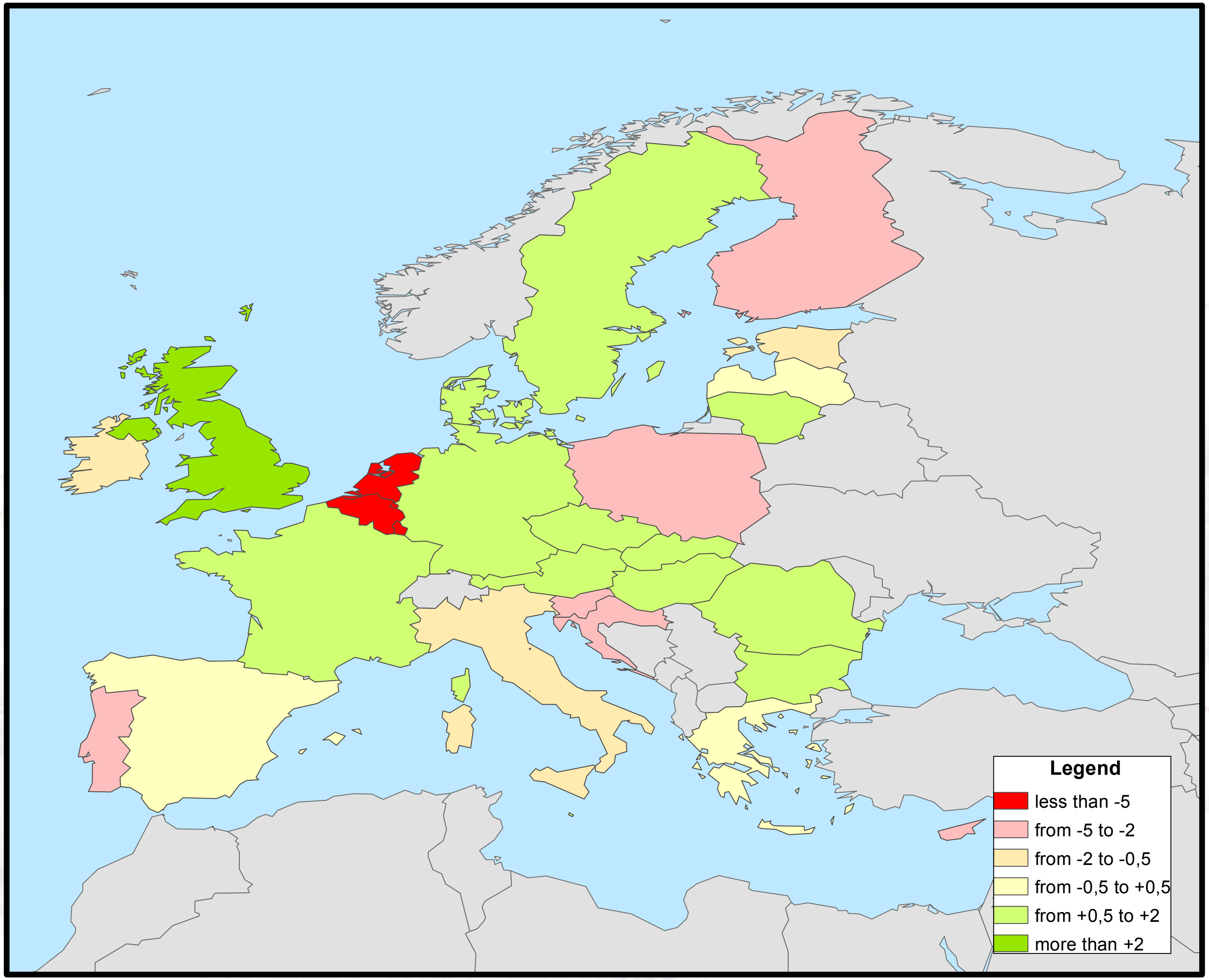
5. Environmental Results

- According with the methodology described, the biocapacity of national cropping systems (BC) has been evaluated considering the weighted average of the crops productions in the three years for each one of the two analysed periods (2002-2004 and 2008-2010).

- The ecological footprint due to the inputs utilized in crops cultivation (EF_{inp}) has been calculated as a three years average for the two periods.

- To calculate the EF due to overproduction, the minimum input production (yield) has been estimated as the tenth percentile of the yield data derived from the 1995-2010 historic series for each crop in each country; using this data the a_{ij} coefficients and the EF_{ovp} in both periods have been evaluated.

5. Environmental Results



Ecological performance of European cropping systems in gha/ha (2008-2010)

5. Environmental Results

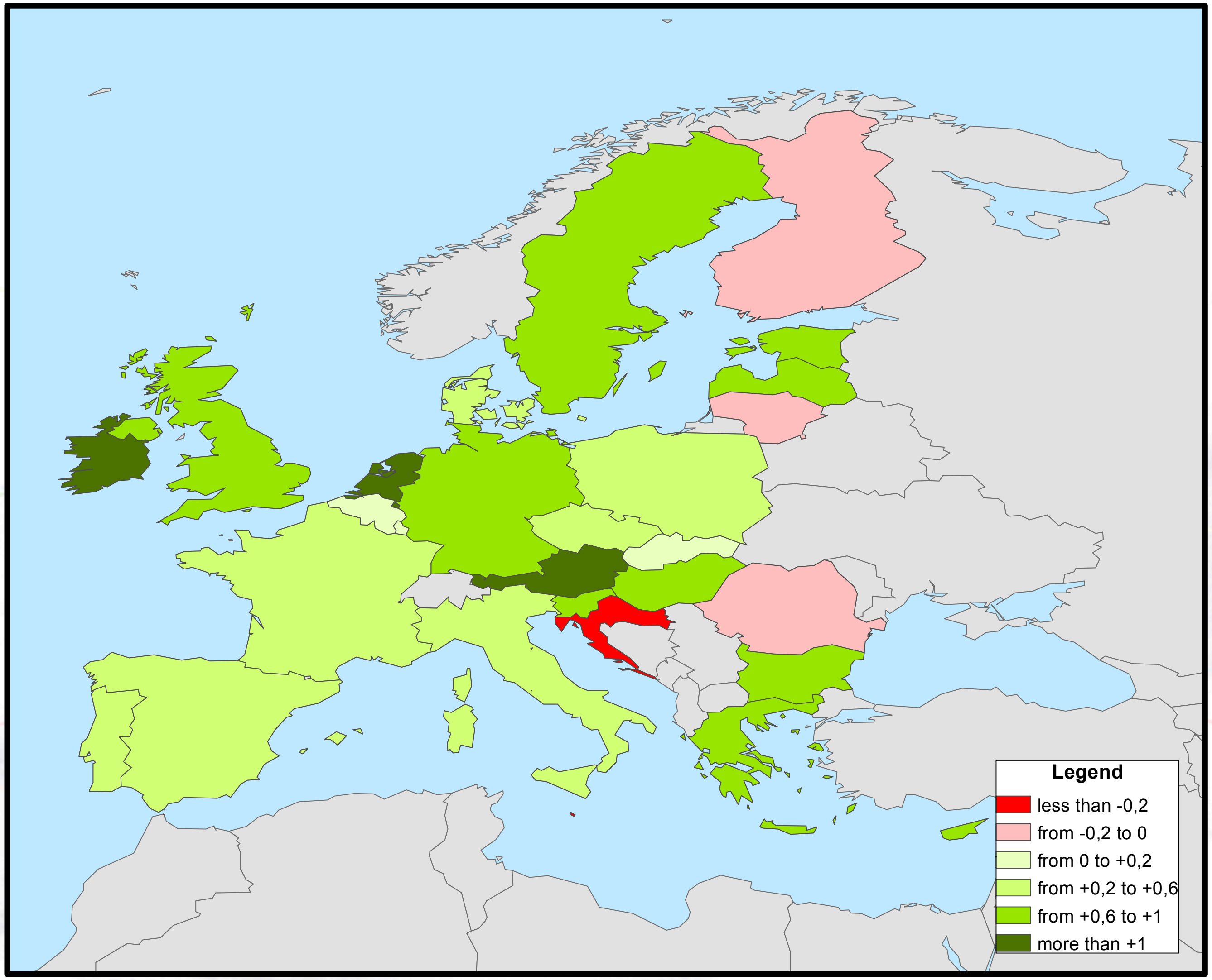
- At European level the results show a low ecological deficit in terms of total gha and, hence, a very small level of unsustainability (-0,03 gha/ha).

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

- Into the Mediterranean Region, countries are generally close to the ecological draw. Indeed, Spain and Italy show a low deficit due to unsuitability in crops choices (Spain) or to the high use of input (Italy), while Greece appears to have a little margin of ecological surplus.

- The areas of unsustainability concern some new-entry countries, such as Poland, Croatia and Slovenia, Finland, Portugal and, with a very high level of unsustainability, the Benelux area: in absolute terms, the overexploitation on natural resource caused by the agricultural systems of this area sucks all the ecological supply made available from French and German cropping systems.

5. Environmental Results



Ecological Balance variation [(2008-2010) (2002-2004)] of European cropping systems [gha/ha]

5. Environmental Results

- The northern-central European countries (Sweden, Germany, UK, Ireland, Austria) contribute with a high improvement in their environmental cropping system performances

- 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 with a more efficient use of inputs, linked to the optimization of the farming techniques, and with a general decrease of cultivations in the less suitable areas, where the scarce productivity of land brings to low yields even in presence of a high input management.

- Evaluating the outcomes of both analyses (the static one referred to 2008-10 and the dynamic one based on the comparison between 2002-04 and 2008-10) it must be considered that the utilized data suffer of several approximations due to the lack and reliability of information collected in the FAOSTAT database.

6. The role of agro-environmental policies in promoting sustainability

- The variation of national cropping systems sustainability have been applied to develop an explorative analysis on the possible effect of agri-environmental payments provided in the second pillar of CAP.

- Data on agri-environmental subsidies (Reg. EEC no.2078/1992; Council Reg. EC no. 1257/1999; Reg. EC no. 1698/2005) for the EU-15 countries from 2003 to 2009 have been collected from the DG AGRI database.

- The values collected were added and then divided for the total utilized agricultural area, obtaining a cumulative payment per hectare over the whole period.

- These data compares the amount of such payments with the variation of the sustainability index as calculated before.

6. The role of agro-environmental policies in promoting sustainability

	Agri-environmental payments 2003-09 [Û/ha]	SI variation 2002-04/2008-10 [gha/ha]
Austria	122,31	2
Belgium-Luxembourg	108	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
Netherland	235,59	10,65
Portugal	142,25	0,34
Spain	228,75	0,48
Sweden	88,42	0,97
UK	89,18	0,72

- Positive correlation coefficient (0.368)
- A simple linear regression model confirms a positive effect of higher payments on a grater improvement of sustainability, with the *b* coefficient having a value of 0,013 gha/€ (on average, a payment of 100 €/ha generated a sustainability improvement of 1,3 gha/ha.
- This coefficient is poorly significant (*p*<0,1 for one tail *t*-test)
- Not significant at all is the *a* coefficient (in our case equal to -0.379), that should represent the variation of sustainability index in absence of agri-environmental subsidies.

7. Conclusions

- The results produced by the study show a substantial generalized improvement of the European cropping systems sustainability trend *(2008 -2010) (2002-2004)*
- From a perspective of policies evaluation and planning, it would be very useful to read this result as a possible effect of interventions aimed at reducing the environmental impact of agriculture
- The regression analysis conducted for this purpose has provided interesting, but not definitive, clues

7. Conclusions

- European agricultural policies can take advantages from tools that take into account not only resources consumption/savings but also the environmental supply production's attitude of farms

- It means to address in more environmental feasible way the economic subsidies and so to contribute to minimize the potential negative impacts of agricultural activities on the environment

- this study proposes a useful contribution to the discussion about the assessment of environmental performances of agriculture, despite the need for theoretical insights and more suitable data

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

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3. Methodological approach

The crop's EF is calculated as the sum of two components:

- the first one is due to the impact associated to the inputs required to manage the crop cultivation (Ef_{inp})
- the second one is linked to the exploitation of land productivity measured as the overproduction with respect to the "minimum" input productivity (Ef_{ovp}) namely the quantity produced by the natural system with the "lowest" level of external inputs

- The results 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.

2. Assessing crops' environmental sustainability

- Farming activities are mainly considered only from the point of view of their negative environmental impact (LCA analysis and greenhouse gasses emissions) - *farmers' choices*.
- Farming activity is able to mitigate the production impacts, ignoring its intrinsic capacity to provide ecosystem services.

- The Ecological Footprint takes into account the resource exploitation due to farming choices (with the EF indicator) and the crop attitude into providing ecological services supply (with the BC indicator)
- Methodological aspects have limited the analyses on agriculture's environmental impact based on the Ecological Footprint

3. Methodological approach

- Both indexes are into functional unit called global hectars (gha)
- The difference between BC an 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
- If EB is negative, the crop is not sustainable since it needs more natural resources than the one provided by the land on which it is cultivated.

4. An assessment of EU countries' cropping system sustainability

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

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

where:

P_{ij} = average productivity of crop j in country i;

Yw_j = world productivity of crop j;

EQF = equivalence factor;

A_{ij} = cultivated area of crop j in country i.

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