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Monitoring and evaluating the sustainability of Italian agricultural system. An emergy decomposition analysis

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ABSTRACT

The agricultural sector is critical for the achievement of sustainable development worldwide. Its present and future sustainability relies on the difficult balance of food production and environmental impact. The need for resource use optimization and increasing reliance on renewable energy, calls for increased development and integration of its supporting, provisioning, regulating and social services (multifunctionality) worldwide, in agreement with the global framework of the Millennium Ecosystem Assessment, the European Union Objectives and other international assessment studies (e.g. the United Nations International Assessment of Agricultural Knowledge, Science and Technology for Development).

The performance of the Italian agricultural system is monitored and evaluated in this paper by means of the emergy accounting method coupled to decomposition analysis techniques, applied to a 25 year time series (1985–2010). The aim of this study is to assess the sustainability of these systems over time as well as to identify the major drivers of performance change, to serve as the basis for future policy scenarios. Two Italian regional agricultural systems (Emilia Romagna, in Northern Italy, and Campania, in Southern Italy) are selected as case studies representative of the Italian agriculture. Results show a steady decrease of cropped land, an increase of the fraction of renewable resource use, an overall increase of sustainability (expressed by emergy indicators) in both regions. The fraction of renewable emergy use increased from 14% to 21% in the Emilia Romagna region and from 23% to 27% in the Campania region, compared to the year 1985, with oscillating behavior over time. The overall Emergy Sustainability Index increased from 14% to 16% in the Emilia Romagna region and from 15% to 19% in the Campania region, recently. The results of decomposition analysis highlight the important role of land use change and labor productivity as major drivers of total emergy use in both agricultural systems. The approach applied in this paper is applicable to the study of other national and regional agricultural sectors wordwide, provided suitable time series of input and output flows are available.

1. Introduction

Sustainable development principles introduced by the Brundtland Report (UNWCED, 1987) pointed out the importance of a sustainable and equitable use of natural resources within and among generations at global level. Agricultural ecosystems are the biggest managed ecosystems worldwide covering about 13 billion hectares (FAO, 2007), with important consequences on economic, social and environmental dynamics (Pettenella and Ciccarese, 2010; Gomiero et al., 2011; Tilman et al., 2011). Moreover the environmental impacts, to which agriculture contributes, in turn affect its food function (Gomiero et al., 2008) calling for an urgent optimization of the trade-off between food security and environmental and social protection (Godfray et al., 2010; Tilman et al., 2011). The performance of the agricultural sector is crucial to the achievement of sustainable development and wellbeing worldwide (Bezlepkina et al., 2010), by promoting sustainable and equitable use of natural resources for all generations (UNWCED, 1987). According to the United States Department of Agriculture (1999), sustainable agriculture should "over the long term, satisfy human needs, enhance environmental quality and natural resource base, make the most efficient use of non-renewable resources and integrate natural biological processes, sustain economic viability, and enhance quality of life". Because of the unsustainable and asymmetric use of energy, minerals and environmental resources (IAASTD, 2008), it is presently difficult to consider modern agriculture as a sustainable way to satisfy human needs (Saifi and Drake, 2008). The Common Agricultural Policy (CAP) rural development program 2007–2013 (European Commission, 2005), implemented

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Nomenclature

R	locally renewable emergy flows
N	locally nonrenewable or slow-renewable emergy flows
F	emergy flows imported from outside (purchased) or supplied as feedback
L	labor directly applied to the process (hours, converted to their emergy units). In this study, the term labor is also used in the decomposition equations to refer to all hours applied directly and indirectly (labor + services) to support the agricultural production.
S	services: Indirect labor applied to the upstream processes that extract, refine and deliver goods to the investigated process. In general, services are quantified in terms of economic cost of indirect labor (€, $), converted to emergy units (seJ)
U	total emergy supporting the process or system under investigation. Sometimes referred to as "total emergy used".
seJ	solar equivalent Joule: unit used to quantify emergy flows
$EYR = U/F = (R+N+F+L+S)/F$	emergy yield ratio
$ELR = (N+F+L+S)/R$	environmental loading ratio
$ESI = EYR/ELR$	Emergy Sustainability Index
ED	empower density: emergy investment per unit of time and per unit of area (seJ s^{-1} ha^{-1})
$\%REN = R/U$	fraction of emergy use that is renewable
$EIR = F/(R+N)$	emergy investment ratio
UEV = U/output	unit emergy value. Generic expression of emergy investment per unit of product of reference flow (seJ g^{-1}; seJ €$^{-1}$, etc.). When the product is measured in energy units (J), the UEV is more frequently termed transformity (seJ J^{-1})
GPV	Gross Production Value
Y	yield. A measure (gram, Joule, kwh, €, etc.) of the process product
AA	area of agricultural land cropped
POP	total resident population of the investigated regions, to be fed by the agricultural products of regional agriculture

by the Regions of the European Union Member States,[1] promotes the production of renewable energies as well as other interventions (such as conservative and restoration soil measures, conversion of arable land to pastureland, and afforestation) by means of regional measures, based on the rationale that agriculture is crucial for the achievement of energy and climate-change objectives (Frascarelli, 2011; Manna, 2012).

In this work we have investigated the environmental and socio-economic sustainability of the agricultural systems of two Italian regions, Emilia Romagna in the Northern Italy, and Campania, in the South. These regional systems are characterized by different trends of climate, soil structure, mix of crops produced, agricultural practices (intensive, integrated, organic, biodynamic, etc.) that affect production results and translate into different values of the indicators (emergy) and the drivers of change (decomposition). Due to these characteristics, these regional systems are representative of the variety of agricultural production patterns in Italy. The coexistence of different agricultural systems (northern versus southern, coastal versus inland, mountain versus plain, intensive versus subsistence, etc.) is frequent in many countries, so that an evaluation approach capable to appreciate diversity and complexity would be a suitable tool for assessment and comparison worldwide.

The case study was performed by means of the emergy accounting method (Odum, 1996; Brown and Ulgiati, 2004b,c) coupled with a decomposition analysis technique (Vehmas, 2009). The latter was applied to a calculated time series of emergy indices and ratios in order not only to compare the two regional agricultural systems on the basis of their emergy performances, but also with the purpose to ascertain which factors, in the investigated period, directly and indirectly affected the changes in imported (F) and non-renewable emergy use (N) and the increase of total emergy use (U). The choice of these indicators for the decomposition test was determined by the fact that they largely characterize the sustainability of an agricultural system.

2. Material and methods

2.1. The investigated regional agricultural systems

The agricultural sectors of Emilia Romagna and Campania regions were investigated over the time period 1985–2010. The Emilia Romagna region is situated in the central-northern part of Italy while Campania is located in the southern part. Fig. 1a and b highlights the large fraction of agricultural area as well as a non-negligible fraction of forested and natural environment. Both regions are characterized by a mixed hilly and plain physical environment. They have a long lasting agricultural tradition characterized by high quality production of cereals such as soft and durum wheat (Fanfani, 2001; Felice, 2011). A large fraction of the cropped areas in both Regions is dedicated to the cultivation of forage for livestock consumption. Emilia Romagna is also specialized in the cultivation of sugar beet, vineyard, peaches, nectarines and pears, while Campania excels in the production of olive, lemons, oranges, tomatoes and vineyard. Both Regions also have an important agro-food industry, the products of which are exported worldwide.[2]

The agricultural productive structure of the Emilia Romagna region consists of farms characterized by an average size of 14.6 ha, while the average farm size in the Campania region is about 4.0 ha. In both Regions the average size is increasing over time because of the gradual expulsion of farmers from business due to the effects of European agricultural policies and market competition that lead to concentration of land into larger farms.[3]

Nowadays intensive agriculture is the dominant productive farming pattern applied in the two Regions. Alternative productive farming systems such as organic and biodynamic, integrated pest management, account respectively for the 6.8% and 11.7% of Emilia Romagna cropped land, while it is 4.2% of total land in Campania. These alternative farming patterns are receiving increasing attention and financial support within the framework of rural development policies.

[1] Campania (2011). Regional Rural Development Plan 2007/2013. Midterm Evaluation. Non-technical summary (march 2011), Available from: http://www.agricoltura.regione.campania.it/psr_2007_2013/monitoraggio/midterm_eva_2010.pdf.

[2] Emilia Romagna (2011) Regional Rural Development Plan 2007/2013. Midterm Evaluation. Non-technical summary (march 2011), Available from: http://www.ermesagricoltura.it/Programmazione-Regionale-dello-Sviluppo-Rurale/Programma-di-Sviluppo-rurale-2007-2013.

[3] Agronotizie (2011), http://agronotizie.imagelinenetwork.com/attualita/2011/07/07/istat-aziende-agricole-in-forte-calo-ma-piu-grandi/13643.